

Mu'tah University
Deanship of the Graduate Studies

The Empirical Relations, Thermal Gradients and Concentration Increments of the Physical Characteristics of Aqueous Honey Solutions and Aqueous Glucose – Insulin Mixtures

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A Thesis Submitted to the Deanship of the Graduate Studies

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Physics, Department of Physics

Mu'tah University, 2014

بسم الله الرحمن الرحيم



MUTAH UNIVERSITY

Deanship of Graduate Studies

جامعة مؤتة

عمادة الدراسات العليا

نموذج رقم (١٤)

قرار إجازة رسالة جامعية

تقرر إجازة الرسالة المقدمة من الطالب منذر فائق السبول الموسومة بـ:

The Empirical Relations,Thermal Gradients and Concentration Increments of the Physical Characteristics of Aqueous Honey Solutions and Aqueous Glucose Insulin Mixtures

استكمالاً لمتطلبات الحصول على درجة الماجستير في **الفيزياء.**

القسم: الفيزياء.

	التوقيع	التاريخ	
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مؤته – الكرك – الاردن
الرمز البريدي: ٦١٧١٠
تلفون: ٩٩-٠٣/٢٣٧٢٣٨٠
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DEDICATION

I dedicate this work to my mother, brothers and sisters, to my dear friends.

Monther Faek Al-Sboul

ACKNOWLEDGEMENTS

First and foremost I should offer my sincere thanks and gratitude to Allah the Great from whom I receive guide and inspiration.

I must extend my deepest thanks and appreciation to my supervisor Dr. Moayad Al-Sabayleh for his guidance, and his encouragement for all the stages of this project. Special thanks must go to Mr. AtallahMoteer for help during the preparation of the samples and for continuous advice during the course of this research. I would also like to thank the technician in the Physics department Mr. Akram Al-Sarayrah for helping me with the necessary equipment’s needed during the course of this project. Appreciation is, also, extended to the staff of Physics departments in Mu'tah University and Al-Hussein Bin Talal University. I would like to thank them very much.

MontherFaek Al-Sboul

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LIST OF ABBREVIATIONS

Term	Abbreviation
Temperature	T
Wavelength	λ
Density of solution	ρ
Cauchy's Equation	CE
The ideal gas constant	R
Speed of light in vacuum	c
EykmanRelation	ER
The Specific Refraction	R_D
The Optical Permittivity	ε
The Activation Energy	∠
Phase velocity	V_{phase}
Reflectance	R(T)
The change in volume	Δv
The deviation of viscosity	$\Delta \eta$
The deviation of refractive index	Δn
The fitting constant of the polynomial equation	A,B,C
Specific refractive index increment	dn/dc
International Units	IU
Absolute (dynamic) viscosity	H
The incident intensity	$I_\circ$
Shear stress	τ
Avogadro's number	N_A
Molecular weight	M_W
Entropy	ΔS
Enthlpy	ΔH
Association of Official Agricultural Chemists	AOAC

Term	Abbreviation
Concentration.	C
Cauchy's coefficient.	A, B, C
Index of refraction	n
Lorentz-Lorenz Equation	LLE
Specific gravity	S_G
Wiener Relation	WR
Argo BiotEquation	ABE
Transmittance	T(T)
Newton Equation	NE
Oster Relation	OR
Heller Relation	HR
Reduced Volume	$v^{\sim}$
Andrade Equation	AE
The electric susceptiblity	X_e
Gladstone – Dale Relation	GD
The temperature gradient of refractive index	dn/dT
Thermal Expansion coefficient	γ_v
The polarizability per unit volume	P_λ
Visible light spectrum	VLS
The absorbed light intensity	I
	$\alpha\lambda$
Linear molecular polarazability	α
Absorption coefficient	

Abstract

The Empirical Relations, Thermal Gradients and Concentration Increments of the Physical Characteristics of Aqueous Honey Solutions and Aqueous Glucose – Insulin Mixtures

Monther Faek Al-Sboul / Mu'tah University, 2014

Densities, refractive indices and viscosities have been experimentally measured at the temperature range 298.15 to 323.15^{o}K (25-50^{o}C)for aqueous honey solutions (with honey concentrations 1%, 2%, 3%, --- 40%, 45%, 50%), aqueous glucose solutions mixed with one gram of insulin (with glucose concentrations 0.5%, 1%, 2%, 3%, 4%, 5%) and aqueous insulin solutions mixed with one gram of glucose (with insulin concentrations 0.5%, 1%, 2%, 3%, 4%). The densities for all samples were pycnometrically measured. The refractive indices were measured at the required temperatures with the thermo stated highly précised Abbes refractometer at the visible D spectral line (Na, λ = 589nm). The dynamic viscosities were measured at the required temperatures using falling ball viscometer for all concentrations of aqueous honey and aqueous glucose insulin mixtures. Optical absorption, dry matter, ash content, moisture content and pH have been experimentally determined for aqueous honey samples. A comparative study has been reported for all samples between the specific refractions of different mixing rule equations (such as Lorentz Lorenz, Oster, Arago Biot, Newton, Gladstone Dale and Eykman) and between viscosities of different mixing rule equations (such as Reynolds, Grunberg Nissan and Mclaughlin Ubbelhold). In this study, it has been verified that the specific refraction in all mixing rules models are independent on temperature. The activation energies for all samples were calculated using Frenkel Eyring Arrhenius type equation. This study illustrates the calculated values versus temperature and concentration of sphere drag coefficient, optical permittivity, electric polarizability, electric susceptibility, normal incidence reflectance, reflection factor, normal incidence transmittance, thermal expansion, entropy, enthalpy, dry content, moisture content, ash content and activation energy. This study gives the polynomial fitting equations of temperature gradients d/dT and concentration increments d/dC of all measured and calculated physical properties.

الملخص

العلاقات المعيارية و ثوابت تأثير الحرارة و التركيز على الخصائص الفيزيائية للمحاليل المائية للعسل و للغلوكوز مع الانسولين

منذر فائق السبول

جامعة مؤتة ، 2014

الكثافة و معامل الانكسار و اللزوجة تم قياسها عند درجات الحرارة بين 25 و 50 سيلسيوس لمحاليل العسل المائية (عند تراكيز العسل 1% , 2% --- 40% , 50%) و محاليل الغلوكوز المائية الممزوجة مع واحد غرام من الانسولين (عند تراكيز الغلوكوز 0.5% , 1% , 2% , 3%, 4% , 5%). كثافة جميع العينات تم قياسها بالطريقة الحجمية. معاملات الانكسار تم قياسها عند درجات الحرارة بواسطة رفراكتوميتر ابي عالي الدقة و عند خط الطول الموجي للضوء المرئي للصوديوم λ=589nm. اللزوجة الديناميكية تم قياسها عند درجات الحرارة لجميع تراكيز محاليل العسل و الغلوكوز مع الانسولين المائية باستخدام جهاز الكرات الساقطة. معاملات الامتصاص البصري و المحتوى الجاف و المحتوى الرمادي و المحتوى المائي و درجة الحموضة تم قياسها لجميع عينات محاليل العسل المائية. تم عرض دراسة مقارنة خضعت لها جميع العينات بين معاملات الانكسار النوعي الخاصة بمعادلات مزج مختلفة (مثل لورنتز لورنز و ارقو بيوت و نيوتن و قلادستون ديل و اوستر و ايكمان) و بين اللزوجة الديناميكية الخاصة بمعادلات مزج مختلفة (مثل رينولدز و غرونبيرغ نيسان و مكلولين أبيلهولد). في هذه الدراسة تم التحقق من ان الانكسار النوعي ثابت مع الحرارة لجميع معادلات النماذج النظرية للمزج. قيم طاقة الحفز لجميع العينات تم حسابها من خلال معادلة فرينكل ايرنج. في هذه الدراسة تم عرض القيم المحسوبة تبعا للحرارة و التركيز لكل من معامل الاعاقة للكرة و السماحية البصرية و الاستقطابية الكهربائية و التأثرية الكهربائية و الانعكاسية البصرية و معامل الانعكاسية و النفاذية البصرية و معامل التمدد الحراري و الانتروبيا و الانثالبيا و المحتوى الجاف و المحتوى المائي و المحتوى الرمادي و طاقة الحفز. هذه الدراسة قدمت المعادلات المعيارية متعددة الحدود التي تصف التغيرات بفعل الحرارة و التغيرات بفعل التركيز لجميع الكميات الفيزيائية المقاسة والمحسوبة.

CHAPTER ONE
INTRODUCTION

1.1. Honey Bee: General Information, Industrial, Food and Health Importance

Honey is a natural sweet flavorful food made by mellifluous bees using the nectar extracted from blossoms of flowers or from sweet secretions of green parts of plants (Adenekan*et al*., 2010). Natural honey is a complex mixture, mainly composed of 80-85% carbohydrates and 15-17% water, *whereas proteins, flavors and aromas, pigments, vitamins, minerals, free* amino acids, and numerous volatile compounds constitute the minor components (Cantarelli*et al*., 2008). From ancient times, honey was found to be a suitable sweetener or healing agent. Honey is a delicious food. It is high in sugars and adds useful varieties to diets (Adams et al., 2010). Honey also contains tiny amounts of several compounds thought to function as antioxidants, including chrysin, pinobanksin, vitamin C, catalase, and pinocembrin (Erejuwa*et al*., 2012). The specific composition of any batch of honey depends on the flowers available to the bees that produced the honey. Honey is farmed and used all over the world, including Jordan. As of 2012, China, Turkey, and Argentina were the top producers of natural honey, followed by Ukraine and the United States. Many Jordanian people are working in the collection of natural honey from the caves and between rocks in the mountains along the eastern side of Dead Sea and Jordan River. Parts of these mountains surfaces are covered by olive, eucalyptus and cedar trees and Mediterranean, steppe, and desert plants. Interestingly, honey has been cited in the Quran, a holy book for Muslims, in reference to its health and medicinal properties. Honey can be identified in three ways through physical, biological and chemical methods, although the physical

examinations usually predominate among the methods (Adams *et al.*, 2010).

From physical viewpoint, honey can be visualized as an aqueous dispersion of varying sized particles (Attri, 2011). Composition and physicochemical characteristics of honey are strongly dependent on its floral origin, geographical, environmental and storage conditions (Manzoor*et al.*, 2013). The shelf life of honey or tendency to crystallize is directly related to its glucose and water contents, origin, age and storage conditions (Joseph *et al.*, 2007). There are differences in the honey's chemical composition which are reflected in many physical properties, such as refractive index, spectral transparency, pH, density, specific rotation, extinction coefficient, viscosity, surface tension, electric conductivity, thermal expansion and polarizability. These determinations are highly useful for determining the quality of honey, which is needed for medicinal treatment and international trade (Manzoor*et al.*, 2013). Some of the results of the physicochemical and biochemical properties such as density, viscosity, thermal conductivity, heat capacity, moisture content, HMF and enzymes obtained were ultimately used to design a model for fabricating processing equipment suitable and affordable to honey producers, processors and packers, as well as setting processing and storage conditions (Bichang'a, 2010). Honey adulteration is a complex problem, which has a significant economic impact; it can be occurred by the addition of different materials. Adulteration, or the addition of foreign substances to honey such as: molasses, starch solution, glucose, sucrose, water and inverted sugar, were studied in many scientific researches (El-Bialee and Sorour, 2011).

1.2. Glucose: General Information, Industrial, Food and Health Importance

Glucose is a simple aldosic monosaccharide found in plants, fruits and honey and it is also known as dextrose, or grape sugar. It is a monosaccharide that is absorbed directly into the bloodstream during digestion. It is an important carbohydrate in biology, which is indicated by the fact that cells use it as a secondary source of energy and a metabolic intermediate (Tappy and Le, 2010). Glucose is one of the main products of photosynthesis and fuels for cellular respiration. Like all hexoses, glucose has the molecular formula $C_6H_{12}O_6$. The name "glucose" comes from the Greek, meaning "sweet wine, must”. The suffix "-ose" denotes a sugar.

Glucose is a common medical analysis measured in blood samples. Eating or fasting prior to taking a blood sample has an effect on the result. A high fasting glucose blood sugar level may be a sign of pre diabetes or diabetes mellitus. Glucose is a ubiquitous fuel in biology. It is used as an energy source in most organisms, from bacteria to humans. Use of glucose may be by aerobic respiration, anaerobic respiration, or fermentation (Peterson *et al.*, 1920). Glucose is the human body's key source of energy, through aerobic respiration, providing about 3.75 kilocalories (16 kilojoules) of food energy per gram. Breakdown of carbohydrates (e.g. starch) yields mono- and disaccharides, most of which is glucose. Through glycolysis and later in the reactions of the citric acid cycle, glucose is oxidized to eventually form CO_2 and water, yielding energy mostly in the form of ATP (Khowala*et al.*, 2008). The insulin reactions, and other mechanisms, regulate the concentration of glucose in the blood (Satoh, 2014). Glucose is a primary source of energy for the brain, so its availability influences psychological processes (Wallace and Barritt, 2002). When glucose is low, psychological processes requiring mental effort (e.g., self-control, effortful decision-making) are impaired.

Glucose is produced commercially via the enzymatic hydrolysis of starch. Many crops can be used as the source of starch. Maize, rice, wheat, cassava, corn husk and sago are all used in various parts of the world (Zainab*et al.*, 2011). In the United States, corn starch (from maize) is used almost exclusively. Most commercial glucose occurs as a component of invert sugar, a roughly 1:1 mixture of glucose and fructose. In principle, cellulose could be hydrolyzed to glucose, but this process is not yet commercially practical (Jacobsen and Wyman, 2000).

Some of the glucose is converted to lactic acid by astrocytes, which is then utilized as an energy source by brain cells, some of the glucose is used by intestinal cells and red blood cells, while the rest reaches the liver, adipose tissue and muscle cells, where it is absorbed and stored as glycogen (under the influence of insulin) (Wallace and Barritt, 2002). Liver cell glycogen can be converted to glucose and returned to the blood when insulin is low or absent; muscle cell glycogen is not returned to the blood because of a lack of enzymes (Shrayyef and Gerich, 2010). In fat cells, glucose is used to power reactions that synthesize some fat types and have other purposes. Glycogen is the body's "glucose energy storage" mechanism, because it is much more "space efficient" and less reactive than glucose itself.

Whether in water or in the solid form, D-glucose is dextrorotatory, meaning it will rotate the direction of polarized light clockwise. The effect is due to the chirality of the molecules, and indeed the mirror-image isomer, L-glucose, is levorotatory (rotates polarized light counterclockwise) by the same amount (Winkler*et al.*, 2010). The strength of the effect is different for each of the five tautomers.

1.3. Insulin: General Information and Medical Importance

Insulin is a peptide hormone produced by beta cells in the pancreas (Nepton, 2013). It regulates the metabolism of carbohydrates and fats by promoting the absorption of glucose from the blood to skeletal muscles and fat tissue and by causing fat to be stored rather than used for energy (Satoh, 2014; Nepton, 2013). Except in the presence of the metabolic disorder diabetes mellitus and metabolic syndrome, insulin is provided within the body in a constant proportion to remove excess glucose from the blood, which otherwise would be toxic (Balammal*et al.*, 2012). When blood glucose levels fall below a certain level, the body begins to use stored sugar as an energy source through glycogenolysis, which breaks down the glycogen stored in the liver and muscles into glucose, which can then be utilized as an energy source (Shrayyef and Gerich, 2010). As a central metabolic control mechanism, its status is also used as a control signal to other body systems (such as amino acid uptake by body cells). In addition, it has several other anabolic effects throughout the body.

When control of insulin levels fails, diabetes mellitus can result. As a consequence, insulin is used medically to treat some forms of diabetes mellitus. Patients with type 1 diabetes depend on external insulin (most commonly injected subcutaneously) for their survival because the hormone is no longer produced internally. Patients with type 2 diabetes are often insulin resistant and, because of such resistance, may suffer from a "relative" insulin deficiency. Some patients with type 2 diabetes may eventually require insulin if dietary modifications or other medications fail to control blood glucose levels adequately. Over 40% of those with Type 2 diabetes require insulin as part of their diabetes management plan (Desbandhu*et al.*, 2011).

Insulin is a very old protein that may have originated more than a billion years ago. The molecular origins of insulin go at least as far back as the simplest unicellular eukaryotes. A part from animals, insulin-like proteins

are also known to exist in Fungi and Protista kingdoms. The human insulin protein is composed of 51 amino acids, and has a molecular weight of 5808 Da (Li *et al.*, 2013). It is a dimer of an A-chain and a B-chain, which are linked together by disulfide bonds. Insulin's name is derived from the Latin *insula* for "island". Insulin's structure varies slightly between species of animals. Insulin from animal sources differs somewhat in "strength" (in carbohydrate metabolism control effects) from that in humans because of those variations (Yogendraji*et al.*, 2011). Porcine insulin is especially close to the human version.

The blood content of insulin can be measured in international units, such as µIU/mL or in molar concentration, such as pmol/L, where 1 µIU/mL equals 6.945 pmol/L. A typical blood level between meals is 8–11 µIU/mL (57–79 pmol/L) (PbPiste, 2013).

Biosynthetic human insulin (insulin human rDNA, INN) for clinical use is manufactured by recombinant DNA technology (Declerck, 2007). Biosynthetic human insulin has increased purity when compared with extractive animal insulins, enhanced purity reducing antibody formation. Researchers have succeeded in introducing the gene for human insulin into plants as another method of producing insulin ("biopharming") in safflower (Spok*et al.*, 2008). This technique is anticipated to reduce production costs.

Several analogues of human insulin are available for clinical therapy. These insulin analogues are closely related to the human insulin structure, and were developed for specific aspects of glycemic control in terms of fast action (prandial insulins) and long action (basal insulins) (Yaturu, 2013; Gossain, 2003; Sheeja*et al.*, 2010). The first biosynthetic insulin analogue was developed for clinical use at mealtime (prandial insulin), Humalog (insulin lispro), it is more rapidly absorbed after subcutaneous injection than regular insulin, with an effect 15 minutes after injection

(Gossain, 2003; Sheeja*et al.*, 2010). Other rapid-acting analogues are NovoRapid and Apidra, with similar profiles. All are rapidly absorbed due to sequence that will reduce formation of dimers and hexamers (monomeric insulins are more rapidly absorbed). Fast acting insulins do not require the injection-to-meal interval previously recommended for human insulin and animal insulins. The other type is long acting insulin; the first of these was Lantus (insulin glargine). These have a steady effect for an extended period from 18 to 24 hours. Likewise, another protracted insulin analogue (Levemir) is based on a fatty acid acylation approach. A myristyric acid molecule is attached to this analogue, which in turn associates the insulin molecule to the abundant serum albumin, which in turn extends the effect and reduces the risk of hypoglycemia. Both protracted analogues need to be taken only once daily, and are used for type 1 diabetics as the basal insulin (Gossain, 2003; Sheeja*et al.*, 2010). A combination of a rapid acting and protracted insulin is also available, making it more likely for patients to achieve an insulin profile that mimics that of the body´s own insulin release. Insulin is usually taken as subcutaneous injections by single-use syringes with needles, via an insulin pump, or by repeated-use insulin pens with disposable needles (Sheeja*et al.*, 2010).

1.4. Physical Properties of Aqueous Honey, Glucose and Sugar Liquids

Physical properties such as density, refractive index, extinction coefficient, polarizability, specific rotation, thermal expansion, PH, viscosity and surface tension are widely used in determining the chemical composition of honey (Ayari*et al.*, 2013; Adams *et al.*, 2010; Attri, 2011) and other sugar liquids (ElGhandoor*et al.*, 2009; Gupta *et al.*, 2012; Hidayanto*et al.*, 2010). These physical properties give useful analytical information for industrial and healthy purposes. El-Bialee (2011) studies

the effect of adulteration on the physical properties of honey. James (2009) reported the effect of water and sugar content on the physical properties of aqueous honey solutions.

In optics the refractive index or index of refraction n of a substance (optical medium) is a dimensionless number that describes how light, or any other radiation, propagates through that medium. It is defined as $n = c/v$, where c is the speed of light in vacuum and v is the speed of light in the substance (Meeteen, 1999). For example, the refractive index of water is 1.33, meaning that light travels 1.33 times slower in water than it does in vacuum. The historically first occurrence of the refractive index was in Snell's law of refraction, $n_1 \sin\theta_1 = n_2 \sin\theta_2$, where θ_1 and θ_2 are the angles of incidence of a ray crossing the interface between two media with refractive indices n_1 and n_2. Wavelength (Thormahlen*et al.*, 1985), temperature (Thormahlen*et al.*, 1985; Mehra, 2003), pressure (Weiss *et al.*, 2012) and concentration (Subedi*et al.*, 2006) are most important factors affecting on refractive index of pure and liquid mixtures.

Refractive index is measured for many reasons. It is clearly important to know the refractive index of materials used for their clarity, such as glasses and solid plastics. In complex fluids such as drinks or foods, the refractive index is a measure of dissolved or submicronic material (Singh *et al.*, 2013). Common industrial applications are to microemulsions to measure their oil/water ratio, to antifreeze to check the glycol/water ratio, and to inaccessible liquids such as the electrolyte of rechargeable cells. The clinical applications of light have stimulated interest in biotissuerefractometry, the refractometry is useful for the analysis of small samples of biofluids (Lin *et al.*, 1999). Refractive index can be measured by different technical methods such as interferometry, deviation, critical angle, Brewster angle, index match, microscopy and

scattering (Meeteen, 1999). Tominaga (2012) reported the effect of glucose concentration on refractive index of aqueous glucose solutions.

The empirical relationship between refractive index and wave length of incident light for a transparent material is called Cauchy's equation (CE). The coefficients of Cauchy's equation can be determined for a material by fitting the equation to the measured refractive indices at known wavelengths (Bashkatov and Genina, 2002). The Cauchy's equation coefficients were determined for many liquid substances (Li and Wu, 2004). In particular, the Cauchy's equation is only valid for regions of normal dispersion in the visible wavelength region. In the infrared, the equation becomes inaccurate, and it cannot represent regions of anomalous dispersion (Gooch, 2011). Different refractive indices mixing rules such as Lorentz Lorenz equation (LLE), ClausiusMossotti relation (CMR), AragoBiot equation (ABE), Newton equation (NE), Maxwell's formula (MF), Gladstone Dale relation (GDR), Heller relation (HR), Eyring and John equation (EJE), Eykman relation (EE), Oster relation (OR) and Wiener relation (WR)are most frequently employed to test the validity of the experimental results (Wankhede, 2012). The most widely used theoretical mixing rules for predicting refractivity of pure and binary liquid mixtures are due to Lorentz–Lorenz equation and Weiner relation (Mehra, 2003; Wankhede, 2012; Narendra*et al.*, 2011; Wiederseiner*et al.*, 2011). The famous Lorentz Lorenz equation links the density and the refractive index of a liquid using the polarizability (Weiss *et al.*, 2012). This empirical relationship was given a sounder theoretical basis by H. A. Lorentz (1880) and L. V. Lorenz (1880), who calculated independently from the electromagnetic theory of light that the quantity see equation (1.1) should be a constant (Barer and Joseph, 1954).Temperature independent quantity and specific refraction (R_D) that characterize electric

polarizability of a substance which was calculated by Lorentz and Lorenz equation as follows (Deosarkar*et al.*, 2013):

$$R_D = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times \frac{1}{\rho} \cdots\cdots\cdots (1.1)$$

Where ρ is the density and n_D is the D-line refractive index. Beysens and Calmettes (1977) discuss the deviations from Lorentz – Lorenz for the temperature dependence of the refractive indices of liquids. Li *et al.* (1994) proposed a modified Lorentz – Lorenz equation for the temperature and concentration dependence of refractive index of liquid mixtures. For a given wavelength Gladstone - Dale found experimentally that (n-1)/ρ was almost independent of temperature for many liquids (Barer and Joseph, 1954).Polarizability is a property of matter, which can measure the ability for the molecules to be, polarized (Khodier, 2002). Polarizabilities of substances determine the dynamic response of a bound system to external electric fields, and provide insight into a molecule's internal structure. There are several scientific reports available on the refractive index of aqueous honey and glucose solutions (Nyau*et al.*, 2013; Nazarian*et al.*, 2010; Tominaga*et al.*, 2012). It is known that the VLS range dispersion relation of optical material could be accurately fitted by the Cauchy empirical formula:

$$n(\lambda) = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \cdots\cdots\cdots (1.2)$$

Where A, B and C are the fitting constants at a given concentration (C), temperature (T) and wave length (λ). We can see in a general way that the refractive index of a substance is related to its density. A light wave passing through an empty space will encounter no atoms, and it will proceed with unchanged velocity. If the same space is now partially filled with atoms or molecules, the incident wave will interact with these as

described above, so that its velocity will be reduced. It is reasonable to assume that since the reduction in velocity is the result of the interaction between the light and atoms in its path, the refractive index will depend on the number of the latter per unit length, or in other words on the density (Barer and Joseph,1954). In liquid mixtures or solutions with concentration C, the specific refractive index increment dn/dc is an important parameter in light scattering measurements, which can be used for the determination of molecular weight, size, and shape (Van Krevelen, 1972). Barer and Joseph (1954) have pointed out that the value of the specific refractive index increment may vary with the nature of the solvent.

Bin Mat Yunus (1988) proposed a method of using refractive index for finding the concentration of aqueous glucose solution. Abu-Jdayil (2002) proposed an empirical method of using refractive index as a tool for finding the water content in Jordanian honeys.

At optical high frequencies the permittivity of a material cannot be measured by the use of electrical methods. However, it is known from Maxwell's theory for electromagnetic waves that for non-magnetic materials the permittivity is related to the refractive index as follows (Kumar and Singh, 2010):

$$n^2 = \varepsilon \cdots\cdots\cdots (1.3)$$

Using the data of refractive index and according to Maxwell's theory for transparent non-magnetic materials (permeability ≈1), we are able to calculate the optical permittivities (ε) at the mentioned wavelengths (Tekin and Tarimci, 2006). Luczycka (2009) reported the effect of temperature on the electric permittivity of honey for electromagnetic field frequency in the range 50Hz to 20 kHz.

Viscosity is one of the most important physical properties of a fluid system. In the food industry, viscosity is one of the most important parameters required in the design of technological process. On the other side, viscosity is also an important factor that determines the overall quality and stability of a food system. From the physicochemical point of view, viscosity means the resistance of one part of the fluid to move relative to another one. Viscosity changes with shear rate, temperature, pressure, moisture, and concentration; all these changes can be modeled by equations. It is well known that the activation energy for Newtonian viscous flow can be easily calculated Arrhenius type relationship. Zaitoun (2001) study the viscosity and activation energy as a function of temperature to compare between Jordanian honeys.

Most of liquid substances expand upon heating and contract when cooled. The change in volume ΔV with temperature ΔT for a substance can be expressed as:

$$\frac{\Delta V}{V_o} = \gamma_T \Delta T \cdots\cdots\cdots (1.4)$$

The constant γ_T called the thermal expansion coefficient of the material. The thermal expansion coefficient can be determined from the thermal effect on volume, density, viscosity, electric permittivity or refractive index. Prod'homme proposed a theoretical equation to calculate optically the thermal expansion of liquids. The densities and thermal expansion coefficients of some vegetable oils has been reported by Klofutar (1997). Thermal expansion coefficients of a transparent substance can be defined optically using refractive index (Gupta *et al.*, 2012). Li (2006) used the specific refraction of Lorentz Lorenz equation to calculate the thermal expansion coefficients.

Ash represents the direct measure of inorganic residues after honey carbonization. This variability in ash content can be explained by the

floral source of the honey. The electrical conductivity is a good criterion related to botanical origin of honey and this is very often used in routine honey control instead of the ash content. The electrical conductivity may also be explained by taking into account the ash and acid content of honey, which reflects the presence of ions and organic acid; the higher their content, the higher the resulting conductivity (Adenekan*et al.*, 2010). Feas (2010) found an empirical linear correlation between the electrical conductivity of honeys and their ash content.

Moisture content of honey is a very important physical characteristic, as it affects various other properties like density, specific gravity, refractive index, viscosity and optical properties. Moisture content also plays an important role in preservation of honey. If the moisture content exceeds 22 percent, honey is likely to ferment. So, for preservation, honey of higher moisture content require the lowering of moisture content, either by partial drying or by mixing the samples with lower moisture content (Attri, 2011). The water activity is an important factor, as it affects the honey stability by limiting or preventing microbial growth. Shafiq (2014) proposed correlation between moisture content and water activity of honey. McNichols (2000) reported the optical activity and the optical absorption for a wide spectral range of aqueous glucose solution.

1.5. Aims of this Study

The aims of our recent study can be summarized in the following points:

1. Measuring and calculating the physical quantities of aqueous honey and aqueous glucose insulin solutions such as refractive index, specific of refraction, density, viscosity, enthalpy, entropy, sphere drag coefficient, reduced volume, optical permittivity, electric polarizability, electric susceptibility, normal incidence reflectance, reflection factor, normal incidence transmittance,

thermal expansion, pH, moisture content, ash content, activation energy and optical absorption.

2. Finding simplified methods for testing and detecting the concentration of aqueous honey and aqueous glucose insulin solutions.
3. Finding the empirical formula that can describe the relation between refractive index, specific of refraction, density, viscosity, enthalpy, entropy, sphere drag coefficient, reduced volume, optical permittivity, electric polarizability, electric susceptibility, normal incidence reflectance, reflection factor, normal incidence transmittance, thermal expansion, PH, moisture content, ash content, dry content, activation energy and optical absorption with concentration and temperature of aqueous honey and aqueous glucose insulin solutions.
4. Finding the empirical formula that can describe the relation between temperature gradient of refractive index, specific of refraction, density, viscosity, enthalpy, entropy, sphere drag coefficient, reduced volume, optical permittivity, electric polarizability, electric susceptibility, normal incidence reflectance, reflection factor, normal incidence transmittance, thermal expansion, PH, moisture content, ash content, dry content activation energy and optical absorption with concentration and temperature of aqueous honey and aqueous glucose insulin solutions.
5. Calculating the values of specific of refraction for all temperatures and concentrations using the modeling equations of Lorentz Lorenz, Oster, Arago Biot, Newton, Gladstone Dale and Eykman using the measured values of refractive index and density.

6. Verification that the specific of refraction is independent on temperature for all theoretical modeling equations.
7. Comparing the accuracy between the applying of Reynolds, Grunberg Nissan and Mclaughlin Ubbelhold equations using the measured values of dynamic viscosity.
8. Calculating the coefficients of thermal expansion using volumetric and optical methods.

CHAPTER TWO

EXPERIMENTAL PROCEDURE

Fourteen liquid samples were prepared by dissolving different weights of Jordanian honey in distilled water to give fourteen concentrations (1%,

2%, 3%, --- 40%, 45%, 50%), six liquid samples were prepared by mixing one gram of insulin with six aqueous glucose concentrations (0.5%, 1%, 2%, 3%, 4%, 5%) and five liquid samples were prepared by mixing one gram of glucose with five aqueous insulin concentrations (0.5%, 1%, 2%, 3%, 4%).

The liquid mixtures were prepared by mass in an air light stopped bottle using an electronic balance (model OHAUS E400 accurate to within ±0.01g). The refractive indices of the samples at the visible D spectral line (Na, λ = 589nm) were obtained with a high-accuracy Abbe refractometer (MEDLINE model CONVEX, see Figure (2.2) in the temperature range from 298.15 to 323.15^{o}K (25-50^{o}C). The temperature of the Abbes refractometer cell was controlled by a circulating thermostated bath (Grant Instruments), see Figure (2.3).

The density of the liquid mixtures, which is required to determine other physical properties, was measured from 25 to 50^{o}C by a pycnometric method (Pycnometer volume 25mL, see Figure (2.4)). The dynamic viscosities of all samples were measured using falling ball viscometer (HAAKE, Germany, see Figure (2.5)). The radian of the used balls in viscometer is 15.67cm and the length of the falling ball tube is 15cm.

Optical absorbance of samples were measured by using (Spectro UV VIS Auto UV-2620, see Figure (2.6)) spectrophotometer (absorbance accuracy of ±0.0001) in the wavelength range (340–700nm) equipped with temperature control thermostat device 10˚C – 75˚C (Accuracy of ± 0.1 ˚C) in Al-Hussein Bin Talal University Laboratory.

The absorbance A is defined as the logarithm of the ratio between the incident intensity of light I_o and the absorbed light intensity I by the material (Hamad, 2013):

$$A = \log[I_o/I] \cdots\cdots\cdots (2.1)$$

PH was measured for pure honey sample at room temperature by using (JENWAY 9500 DO_2 Meter), shown in figure (1.7). Ash content was determined for pure honey sample by igniting at 595.2 ^{o}C in a furnace to constant mass. Dry content was measured by drying the pure honey in Oven AT 150 ^{o}C for 2 hr, see figure (2.8). Moisture content of the pure honey sample was determined from the ash value, to analyze the change in mass of pure honey sample with increasing temperature we use thermogravimetricanalyzer (Tarsus TG 209) shown in figure (2.9). To measure the mineral content of pure honey sample, we use the energy dispersive X ray fluorescence spectrometer (Shimadzn EDX-700 see figure (2.1)).



Figure (2.1)
Energy dispersive x ray fluorescence spectrometer



Figure (2.2)
Abbe Refractometer



Figure (2.3)
Circulating Thermostated Bath



Figure (2.4)
Pycnometer



Figure (2.5)
Falling Ball
Viscometer

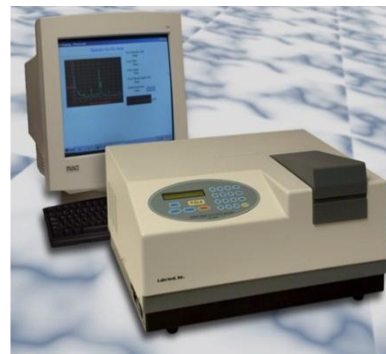


Figure (2.6)
Spectrophotometer







Figure (2.7) (2.8) Figure (2.9) FigurePH meter OvenThermogravimetricanalyzer

CHAPTER THREE

RESULTS AND DISCUSSION

3.1. Thermal Gradient and Concentration Increment of Refractive Index and Phase Velocity of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

Refractive index of liquid mixtures and solutions is fundamentally interesting and practically useful parameter. In addition to the molecular constituents, the wavelength, temperature, pressure and concentration are the most important factors affecting the refractive indices of liquid mixtures and solutions. Prediction of refractive indices of dual liquid mixtures is essential for the determination of composition of dual liquid

mixtures (Mehra, 2003). Refractive index measurements are related to density, viscosity, thermal expansion, optical absorption, optical activity, conductivity and the other analytical data are very usefully health and industry for common substances which include oils, waxes, sugar syrups etc. A comprehensive literature survey reveals that there is no such data on these systems, the components of which have wide applicability in chemical analyses, quality control and industry. The variation in magnitude of refractive index (n) as a function of temperature, or the thermal coefficient (or thermal gradient), dn/dT, is a very important property for photonic materials and devices. It plays vital role in many areas of material science according to thin film technology, integrated optics, waveguide optics and fiber optics. The refractive index of liquid mixtures or solutions change with concentration; this change can be characterized by concentration increment of refractive index dn/dC. Knowledge of specific refractive index incrementof organic liquid substances is important for the determination of molecular weights by light-scattering measurements (Barer, 1954). The refractive index can be measured with higher degree of accuracy than permittivity ε; in many cases the measurement of optical and electrical properties of a substance can be replaced by measuring refractive index. Furthermore, thermal gradient of refractive index can also be used to calculate thermal expansion coefficient (Li *et al.*, 2006; Kang *et al.*, 2002). As we know, refractive index of a medium depends on the density of medium as well as temperature. Decrease in solution concentration is proportional with the decrease in density and refractive index. Recently, there are many works on investigating dn/dT and dn/dC of different food, pharmaceuticals and industrial materials (Chen *et al.*, 2008).

The refractive indices of all aqueous honey liquids and aqueous glucose/insulin mixed samples were measured by Abbe refractometer in the temperature ranged from 298.15 to 323.15°K (25-50°C) by using monochromatic visible D spectral line of sodium (λ=589nm). Figures (3.1.1) and (3.1.7) show the experimental results of aqueous honey solutions refractive index versus temperatures (298.15 to 323.15°K) and versus concentrations (1%, 2%, 3%, --- 40%, 45%, 50%) respectively of aqueous honey solutions. Figure (3.1.8) shows the experimental results of aqueous glucose solutions mixed with one gram of insulin of refractive index versus concentration (0.5%, 1%, 2%, 3%, 4%, and 5%) for different temperatures (298.15 to 323.15°K). Figure (3.1.9) shows the experimental aqueous insulin solutions mixed with one gram of glucoseof the refractive index versus concentration (0.5%, 1%, 2%, 3%, and 4%) for different temperatures (298.15 to 323.15°K).

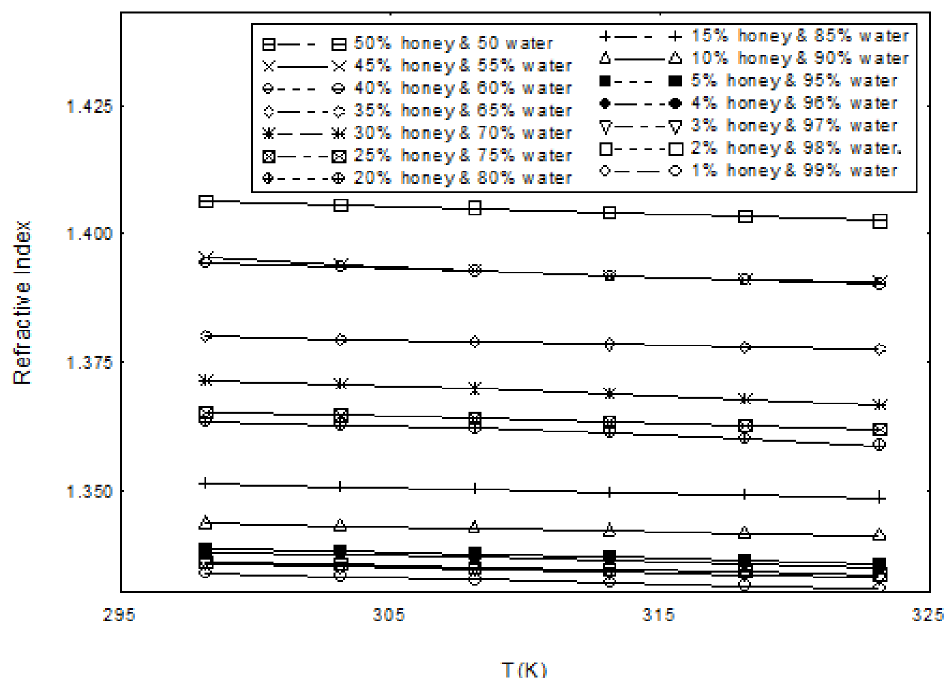


Figure (3.1.1): Refractive index measured versus temperature of different aqueous honey solutions concentrations.

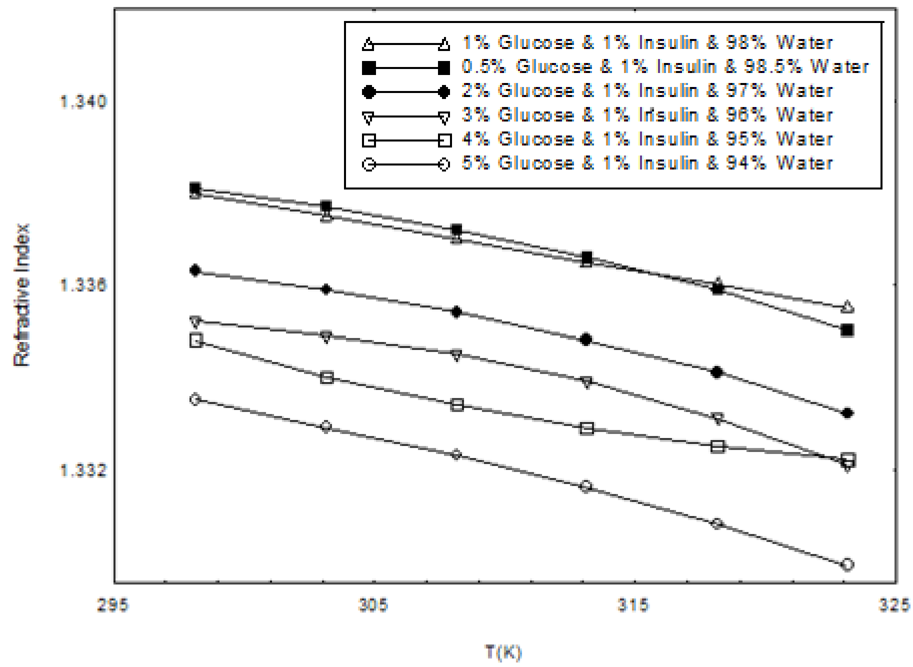


Figure (3.1.2): Refractive index measured versus temperaturefor different concentrationsof aqueous glucose solutions mixed with one gram of insulin.

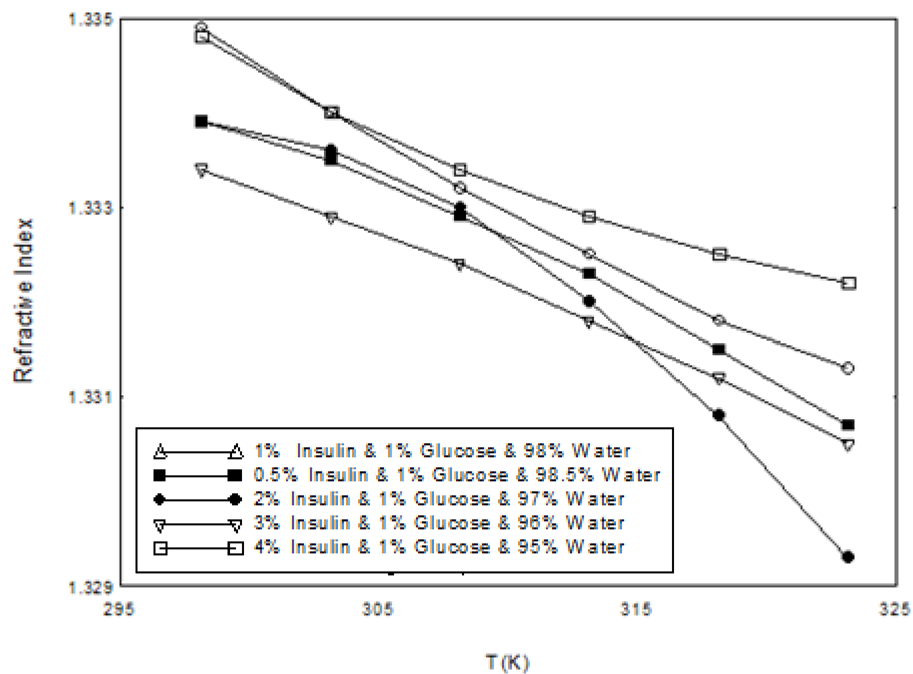


Figure (3.1.3): Refractive index measured versus temperaturefor different concentrations of aqueous insulin solutions mixed with one gram of glucose.

From figures (3.1.1) to (3.1.3) it is noticed that the refractive index slightly decreases linearly with increasing temperature and increases with increasing of concentration for all aqueous honey solutions. The slight decrease of refractive index in aqueous honey samples caused by temperature can be explained by the relation between the behavior of refractive index and density with heat. It means that the refractive index decreases with the decreasing density; which caused by the increase of temperature. Raising the temperature of samples may lead to a break in some chemical bonds in organic materials containing of honey or may cause enlarging the space between molecules. This effect of temperature changes the space between the molecules which can change the velocity of light passing through it and accordingly changed the refractive index of the liquid solution. The values of measured refractive index of aqueous honey solutions for all concentrations and for different temperatures ranged from 1.3308 to 1.4064. From figure (3.1.2) it is observed that the refractive index of aqueous glucose solutions mixed with one gram of insulin increases with increasing concentration and temperature. The values of measured refractive index of aqueous glucose solutions mixed with one gram of insulin for all concentrations and for different temperatures ranged from 1.3299 to 1.3380. Also from figure (3.1.3) it shows that the refractive index of aqueous insulin solutions mixed withone gram of glucose a slight decrease with increasing concentration andan increase with increasing temperature. The values of measured refractive index of aqueous insulin solutions mixed with one gram of glucose for all concentrations and for different temperatures are ranged from 1.3313 to 1.3339. Barer (1954) has pointed out that the refractive index may vary with the nature of solvent. All solvents with lower refractive index and lower molecular weight can decrease the refractive index of liquids with a high value of refractive index and high molecular

weight. In this study distilled waterwas used as a solvent and it is clearly seen from all figures that distilled water decreases the refractive index of solutions. From figures (3.1.8) and (3.1.9) it canbe concluded that glucose concentration increases refractive index but insulin concentration decreases it. In most instances the usefulness of refractive index is its ability to indicate, indirectly, something about the state or structure of the material under consideration. In this case; the refractive index can indirectly measures the concentration of aqueous honey and aqueous glucose insulin solutions. There are some reported attempts in the literature to develop empirical equations that yield the index of refraction of aqueous honey and aqueous glucose insulin solutions as a function of several parameters such as temperature, concentration, pressure and wavelength (Abu-Jdayil *et al.*, 2002 and Nyau *et al.*, 2013).Since we are interested in the index of refraction of aqueous honey and aqueous glucose insulin solutions, the following polynomial equations will be useful. The effect of temperature on refractive index could be accurately fitted by the polynomial equation:

$$n = A_{on} + B_{on}T + C_{on}T^2 \cdots\cdots\cdots (3.1.1)$$

The fitting constants A_{on}, B_{on}, and C_{on} are given in tables (3.1.1), (3.1.2) and (3.1.3) for all concentrations of aqueous honey and aqueous glucose insulin solutions.

Table (3.1.1): The fitting constants of temperature polynomial model of refractive index for all concentrations of aqueous honey solutions.

Concentration %	C_{on} (k^{-2})	B_{on} (k^{-1})		R^2
1%	4.00E-08	-0.00014716	1.37412905	0.994
2%	3.70E-07	-0.00032636	1.40046200	0.992
3%	-3.90E-07	0.00012900	1.33197729	0.999
4%	-1.69E-06	0.00092840	1.21127328	0.998
5%	-2.30E-06	0.00131600	1.15154800	0.995

Table (3.1.2): The fitting constants of the temperature polynomial model of refractive index for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_{on} (k^{-2})	B_{on} (k^{-1})		R^2
0.5%	2.E-06	-0.0016	1.5430	0.999
1%	2.E-06	-0.0016	1.5926	0.999
2%	-1.E-06	0.0005	1.2715	0.999
3%	-6.E-06	0.0035	0.8110	0.999
4%	-2.E-06	0.0011	1.1797	0.999

Concentration %	C_{on} (k^{-2})	B_{on} (k^{-1})		R^2
0.5%	-2.0E-06	0.0009	1.2178	0.9998
1%	2.0E-06	-0.0016	1.5926	0.9996
2%	-4.0E-06	0.0021	1.0208	0.9997
3%	-2.0E-06	0.0013	1.1458	0.9997
4%	-2.0E-06	0.0013	1.1476	0.9997
5%	-2.0E-06	-0.0001	1.3678	1

Table (3.1.3): The fitting constants of the temperature polynomial model of refractive index for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

The temperature gradients of refractive index dn/dT for all concentrations of aqueous honey and aqueous glucose insulin solutions are shown respectively in figures (3.1.3), (3.1.4) and (3.1.5). These linear temperature gradients were fitted by a polynomial equation:

$$\frac{dn}{dT} = A_n + B_n T + C_n T^2 \cdots\cdots\cdots (3.1.2)$$

Where $A_n = B_{on}$ and $B_n = 2C_{on}$. The constants of the polynomial equation of temperature gradient for all concentrations of aqueous honey and

aqueous glucose insulin solutions were shown respectively in tables (3.1.4), (3.1.5) and (3.1.6).

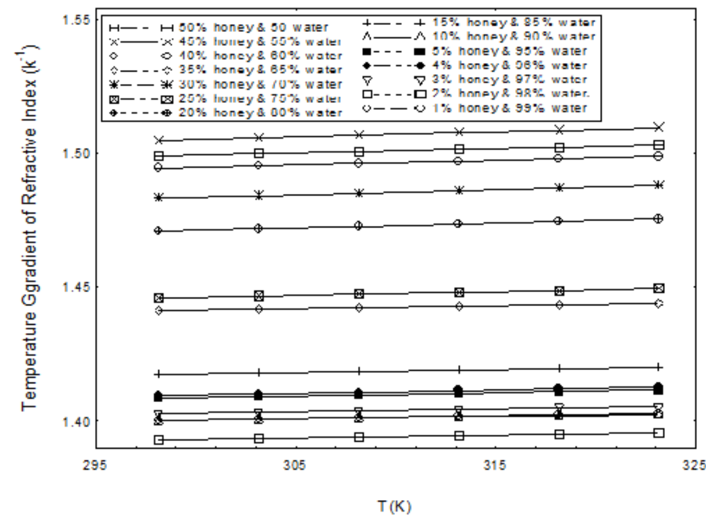


Figure (3.1.4): Temperature gradients of refractive index measured versus temperature for different concentrations of aqueous honey solutions.

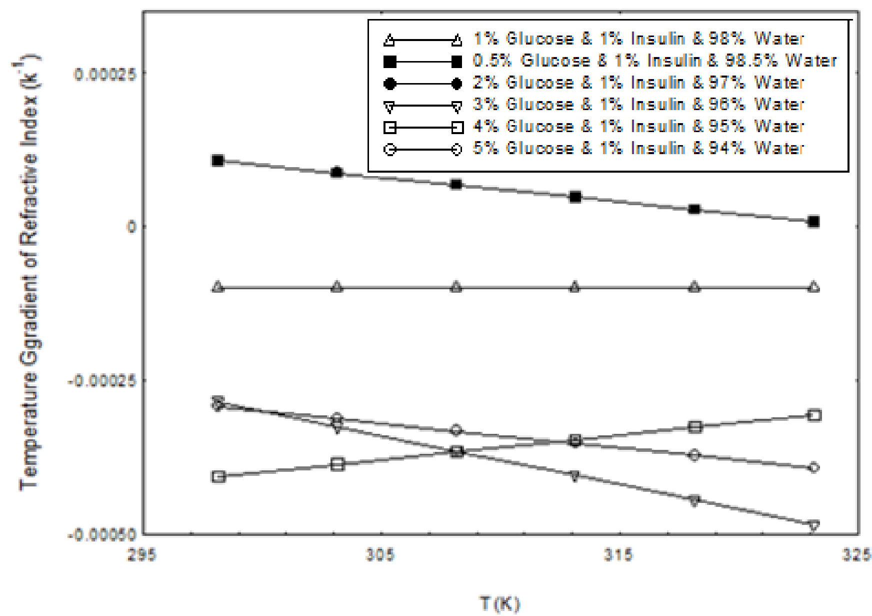


Figure (3.1.5): Temperature gradients of refractive index measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_n (k^{-1})	B_n (k^{-2})		R^2
1%	-0.00014716	8.00E-08	0	1
2%	-0.00032636	7.40E-07	0	1
3%	0.00012900	-7.80E-07	0	1
4%	0.00092840	-5.38E-06	0	1
5%	0.00131600	-2.60E-06	0	1

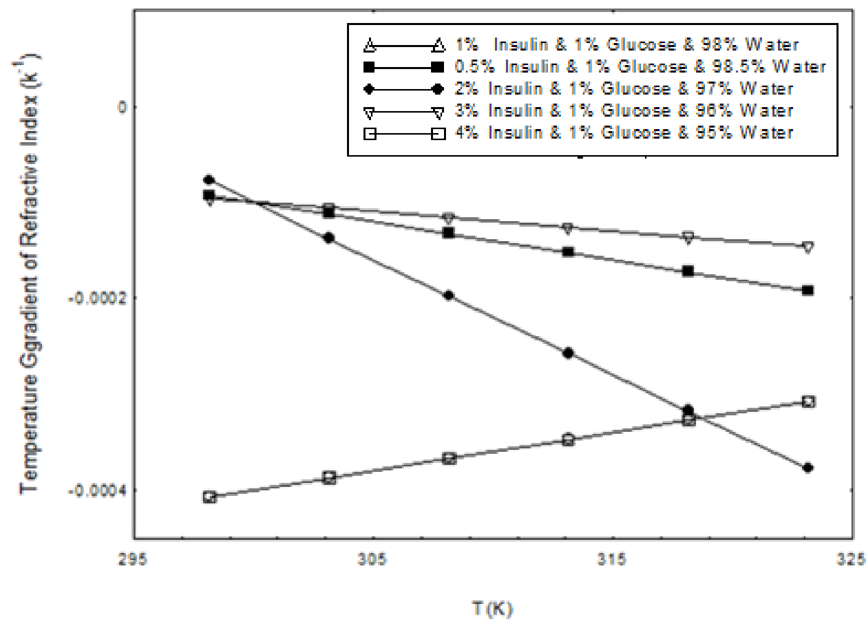


Figure (3.1.6): Temperature gradients of refractive index measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

Table (3.1.4): The fitting constants of temperature polynomial model of temperature gradient of refractive index for all concentrations of aqueous honey solutions.

Table (3.1.5): The fitting constants of temperature polynomial model of temperature gradient of refractive index for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_n (k^{-1})	B_n (k^{-2})		R^2

0.5%	0.0009	-4.E-06	0	1
1%	-0.0016	4.E-06	0	1
2%	0.0021	-8.E-06	0	1
3%	0.0013	-4.E-06	0	1
4%	0.0013	-4.E-06	0	1
%5	-0.0001	-4.E-06	0	1

Table (3.1.6): The fitting constants of temperature polynomial model of temperature gradient of refractive index for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_n (k^{-1})	B_n (k^{-2})		R^2
0.5%	-0.0016	4.E-06	0	1
1%	-0.0016	4.E-06	0	1
2%	0.0005	-2.E-06	0	1
3%	0.0035	-6.E-06	0	1
4%	0.0011	-12.E-06	0	1

The effect of concentration on refractive indexfor all temperatures of aqueous honey and aqueous glucose insulin solutions could be accurately fitted by the polynomial equation:

$$n = A_{on} + B_{on} C + C_{on} C^2 \cdots\cdots\cdots \ (3.1.3)$$

The fitting constants A_{on}, B_{on}, and C_{on} are given in tables (3.1.7), (3.1.8) and (3.1.9) for all temperatures of aqueous honey and aqueous glucose insulin solutions.

Table (3.1.7): The fitting constants of concentration polynomial model of refractive index for all temperatures of aqueous honey solutions.

T(K)	C_{on}	B_{on}		R^2
298.15 (k)	-0.0756	0.2609	1.3929	0.8601
303.15 (k)	-0.0771	0.2623	1.3934	0.8589
308.15 (k)	-0.0789	0.2639	1.3938	0.8578
313.15 (k)	-0.0799	0.2651	1.3943	0.8568
318.15 (k)	-0.0805	0.2661	1.3948	0.8554
323.15 (k)	-0.0825	0.2677	1.3953	0.8546

Table (3.1.8): The fitting constants of concentration polynomial model of refractive index for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_{on}	B_{on}		R^2
298.15 (k)	-0.763	0.143	1.333	0.948
303.15 (k)	-1.219	0.173	1.332	0.965
308.15 (k)	-1.417	0.185	1.331	0.97
313.15 (k)	-1.386	0.186	1.33	0.969
318.15 (k)	-1.126	0.173	1.33	0.956
323.15 (k)	-0.496	0.14	1.329	0.914

Table (3.1.9): The fitting constants of concentration polynomial model of refractive index for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_{on}	B_{on}		R^2
298.15 (k)	-2.5	0.175	1.33	1
303.15 (k)	-4	0.27	1.329	1
308.15 (k)	-3.5	0.235	1.329	1
313.15 (k)	0.5	-0.005	1.331	1
318.15 (k)	5.5	-0.315	1.335	1
323.15 (k)	13	-0.77	1.34	1

Figures (3.1.7), (3.1.8), and (3.1.9) show the refractive index versus concentration for all temperatures of aqueous honey and aqueous glucose and insulin solutions.

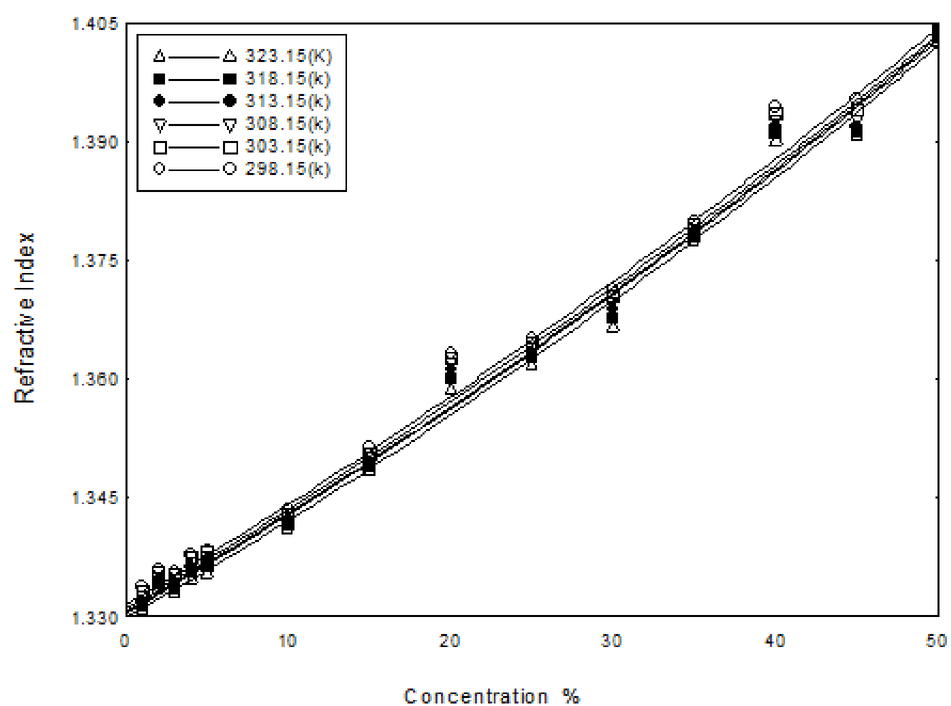


Figure (3.1.7): Refractive index measured versus concentration of different temperatures aqueous honey solutions temperatures.

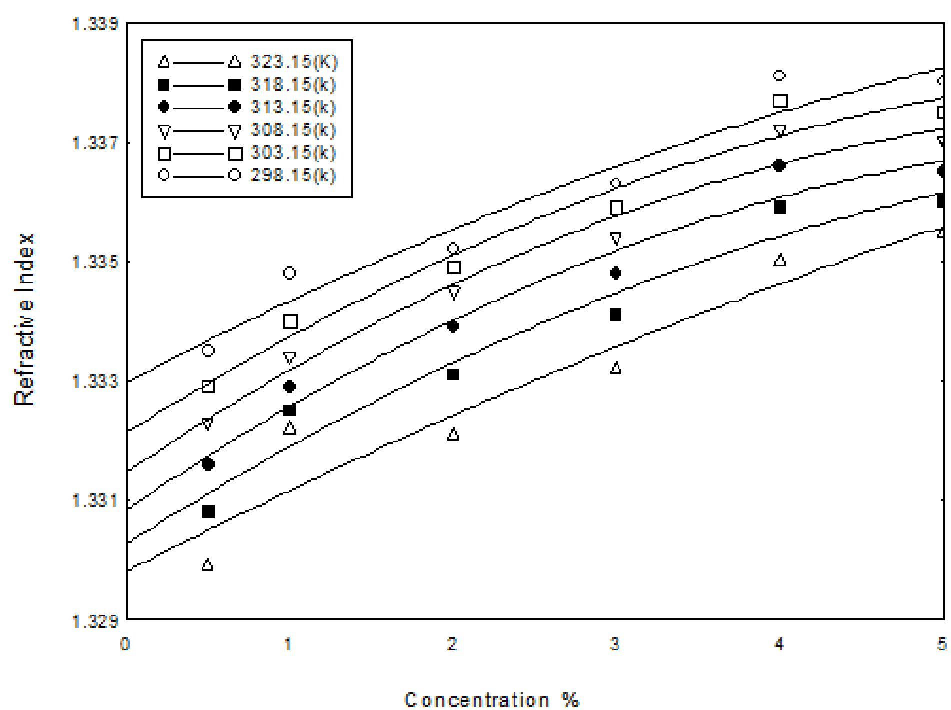


Figure (3.1.8): Refractive index measured versus concentration of different aqueous glucose solutions temperatures mixed with one gram of insulin.

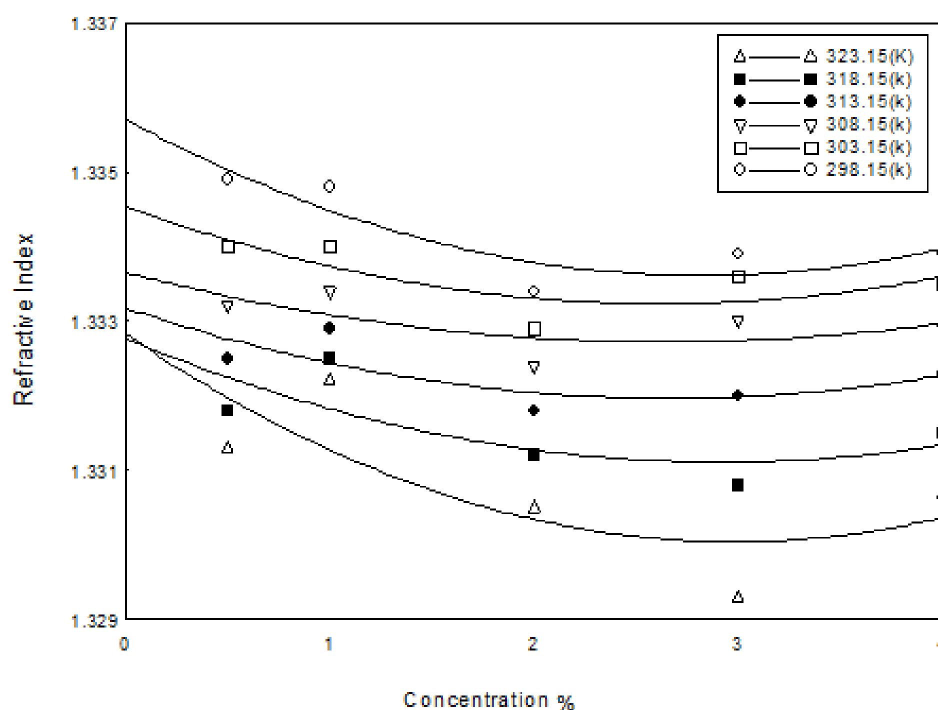


Figure (3.1.9): Refractive index measured versus concentration of different temperatures aqueous insulin solutions temperatures mixed with one gram glucose.

The effect of concentration can be characterized clearly by using concentration increment dn/dC. The concentration increments of refractive index for all temperatures of aqueous honey and aqueous glucose insulin solutions are shown respectively in figures (3.1.9), (3.1.10) and (3.1.11).These linear concentration increments were fitted by a polynomial equation:

$$\frac{dn}{dC} = A_n + B_n C + C_n C^2 \cdots\cdots\cdots \text{(3.1.4)}$$

Where $A_n = B_{on}$ and $B_n = 2C_{on}$. The constants of the polynomial equation of concentration increments for all temperatures of aqueous honey and aqueous glucose insulin solutions were shown respectively in tables (3.1.10), (3.1.11) and (3.1.12).

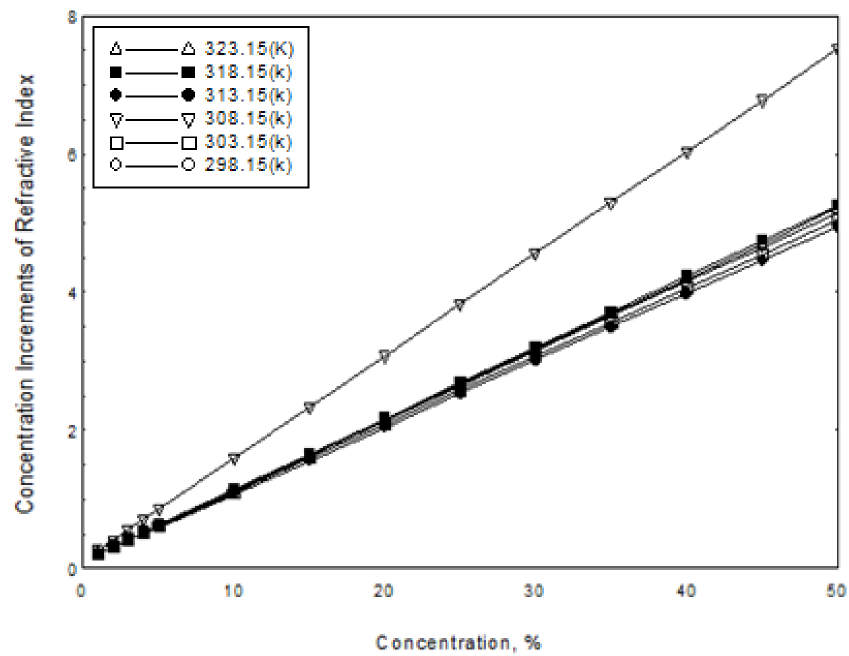


Figure (3.1.10): Concentration increment of refractive index measured versus concentration for different temperatures of aqueous honey solutions.

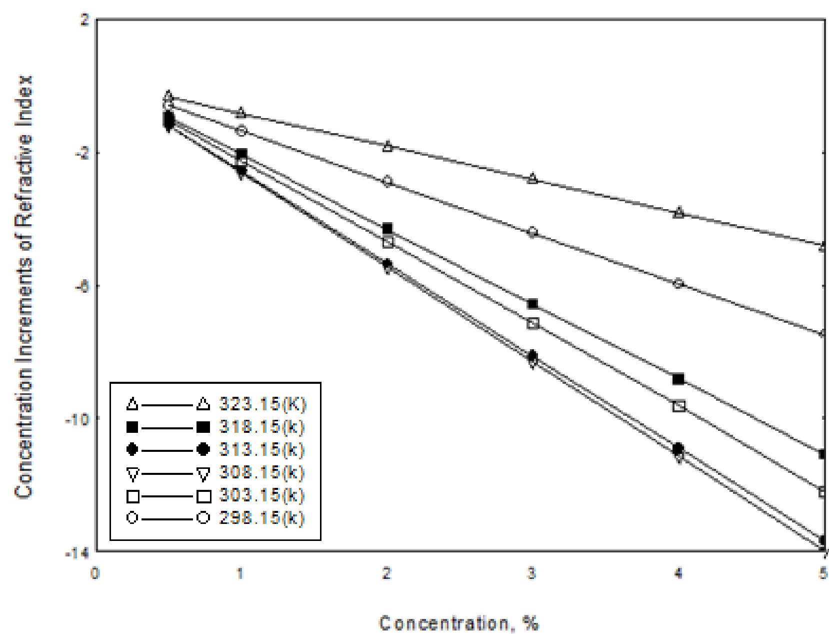


Figure (3.1.11): Concentration increment of refractive index measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

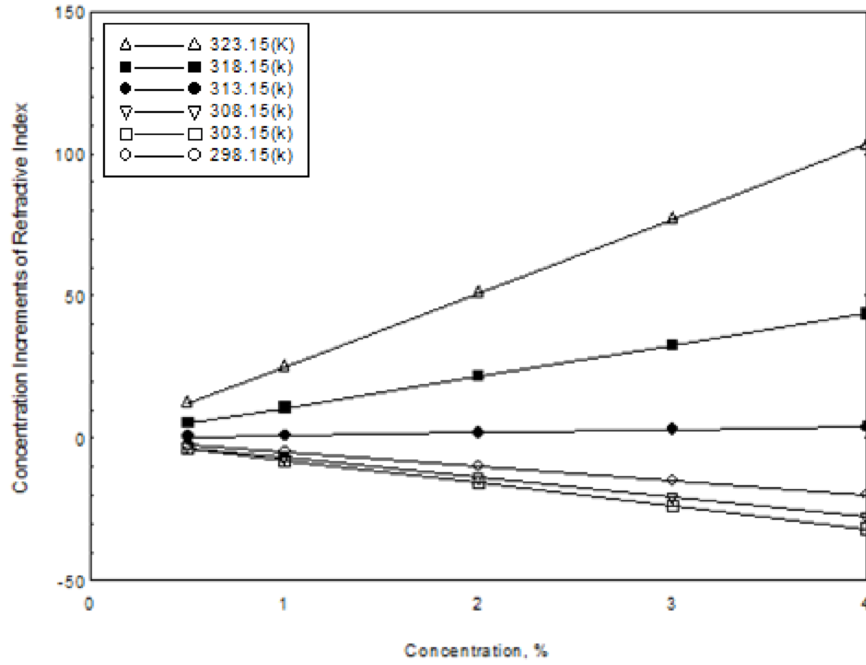


Figure (3.1.12): Concentration increment of refractive index measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

Table (3.1.10): The fitting constants of concentration polynomial model of concentration increment of refractive index for all temperatures of aqueous honey solutions.

T(K)	A_n	B_n		R^2
298.15 (k)	0.2609	-0.1512	0	1
303.15 (k)	0.2623	-0.1542	0	1
308.15 (k)	0.2639	-0.1578	0	1
313.15 (k)	0.2651	-0.1598	0	1
318.15 (k)	0.2661	-0.161	0	1
323.15 (k)	0.2677	-0.165	0	1

Table (3.1.11): The fitting constants of concentration polynomial model of concentration increment of refractive index for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_n	B_n		R^2
298.15 (k)	0.143	-1.526	0	1
303.15 (k)	0.173	-2.438	0	1
308.15 (k)	0.185	-2.834	0	1
313.15 (k)	0.186	-2.772	0	1
318.15 (k)	0.173	-2.252	0	1
323.15 (k)	0.14	-0.992	0	1

Table (3.1.12): The fitting constants of concentration polynomial model of concentration increment of refractive index for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_n	B_n		R^2
298.15 (k)	0.175	-5	0	1
303.15 (k)	0.27	-8	0	1
308.15 (k)	0.235	-7	0	1
313.15 (k)	-0.005	1	0	1
318.15 (k)	-0.315	11	0	1
323.15 (k)	-0.77	26	0	1

The phase velocity v_p of a wave is the rate at which the phase of the wave propagates in space. It is the velocity at which the phase of any frequency component of the wave travels. For such a component, any given phase of the wave (for example, the crest) will appear to travel at the phase velocity. The phase velocity is given in terms of the wavelength λ and period τ as

$$v_p = \lambda/\tau \cdots\cdots\cdots (3.1.5)$$

Also the phase velocity of electromagnetic waves propagates through any medium can be obtained by using refractive index n and speed of light c by the following simple relation (Galisteo-Lopez *et al.*, 2006)

$$v_p = c/n \cdots\cdots\cdots (3.1.6)$$

The phase velocity of all aqueous honey liquids and aqueous glucose/insulin mixedsamples were calculated by using the measured values of refractive index in the temperature are ranged from 298.15 to 323.15^{o}K (25-50^{o}C) for the visible D spectral line of sodium (λ=589nm). Figures (3.1.13) and (3.1.14) show phase velocity versus temperature (298.15 to 323.15^{o}K) and versus concentration (1%, 2%, 3%, --- 40%, 45%, 50%) respectively of aqueous honey solutions. Figure (3.1.15) and (3.1.16) show phase velocity versus temperature (298.15 to 323.15^{o}K) and versus concentration (0.5%, 1%, 2%, 3%, 4%, and 5%) respectively of aqueous glucose solutions mixed with one gram of insulin.

Figure (3.1.16) and (3.1.14) show phase velocity versus temperature (298.15 to 323.15^{o}K) and versus concentration (0.5%, 1%, 2%, 3%, and 4%) respectively of aqueous insulin solutions mixed with one gram of glucose.

From figures (3.1.13) and (3.1.14) they show that the phase velocity of the sodium D spectral line wave propagates through aqueous honey solution slightly increased with increasing temperature but decreased with increasing honey concentration. This means that the light propagates faster in the medium with lower density.

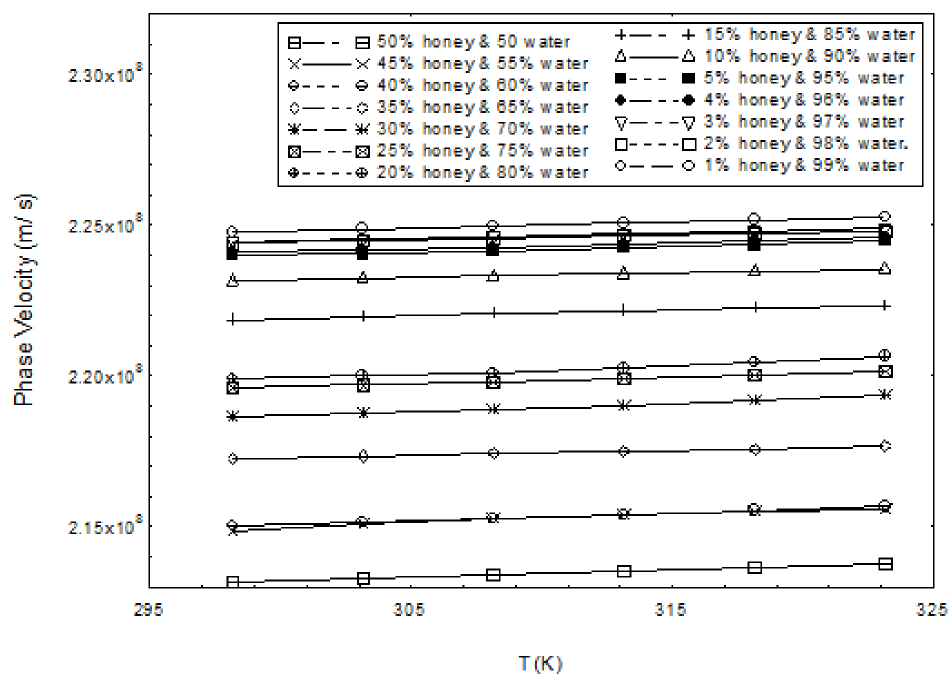


Figure (3.1.13): Phase velocity of sodium D spectral line versus temperature for different concentrations of aqueous honey solutions.

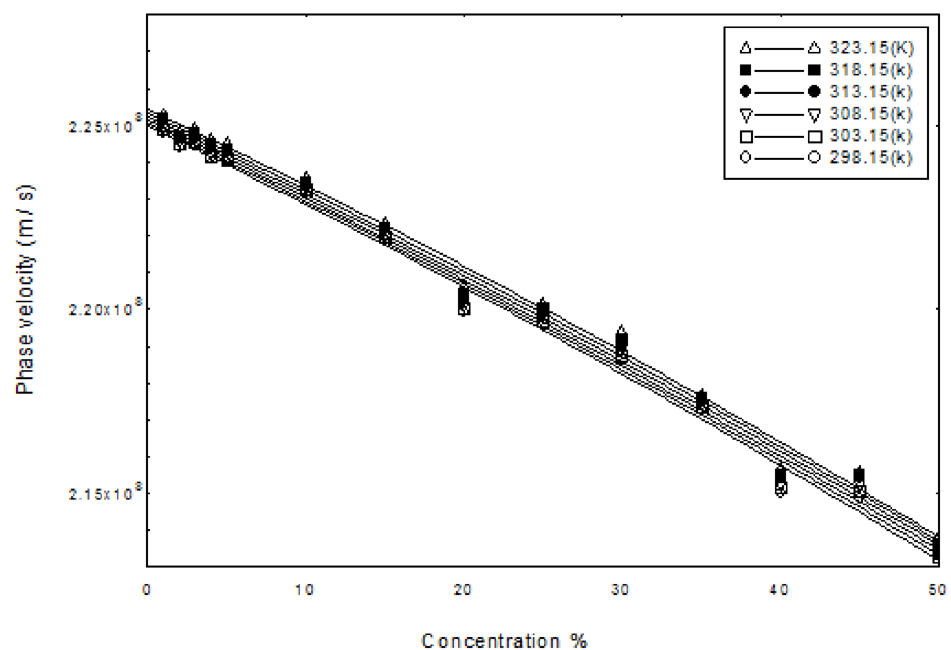


Figure (3.1.14): Phase velocity of sodium D spectral line versus concentration for different temperatures of aqueous honey solutions.

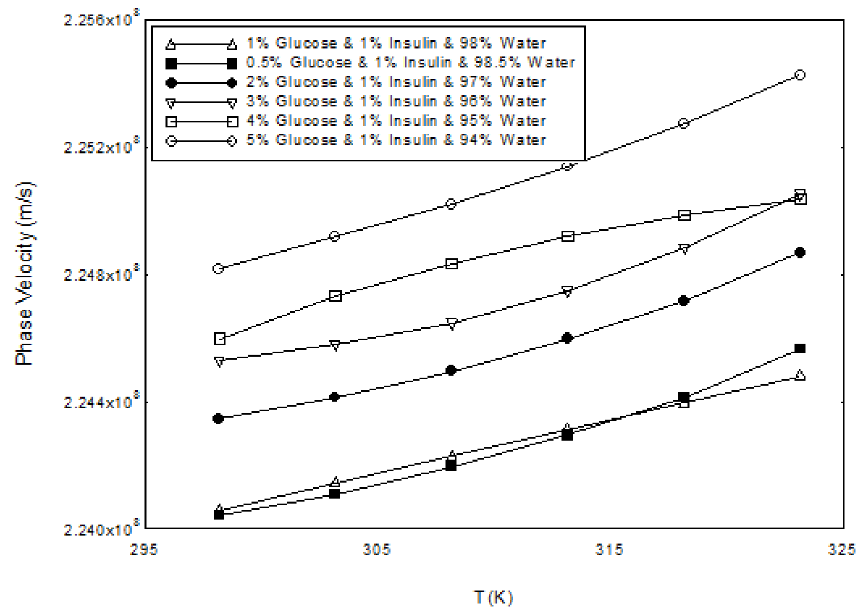


Figure (3.1.15): Phase velocity of sodium D spectral line versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

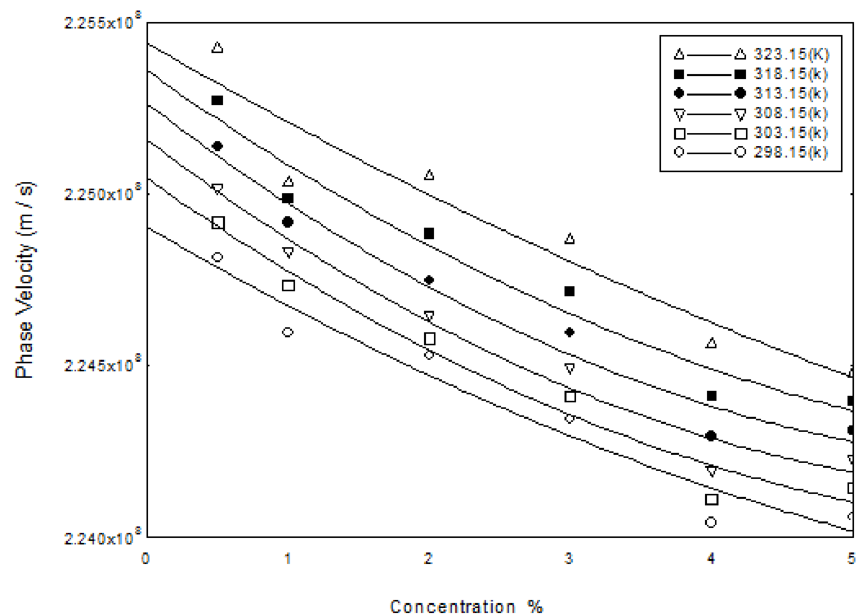


Figure (3.1.16): Phase velocity of sodium D spectral line versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

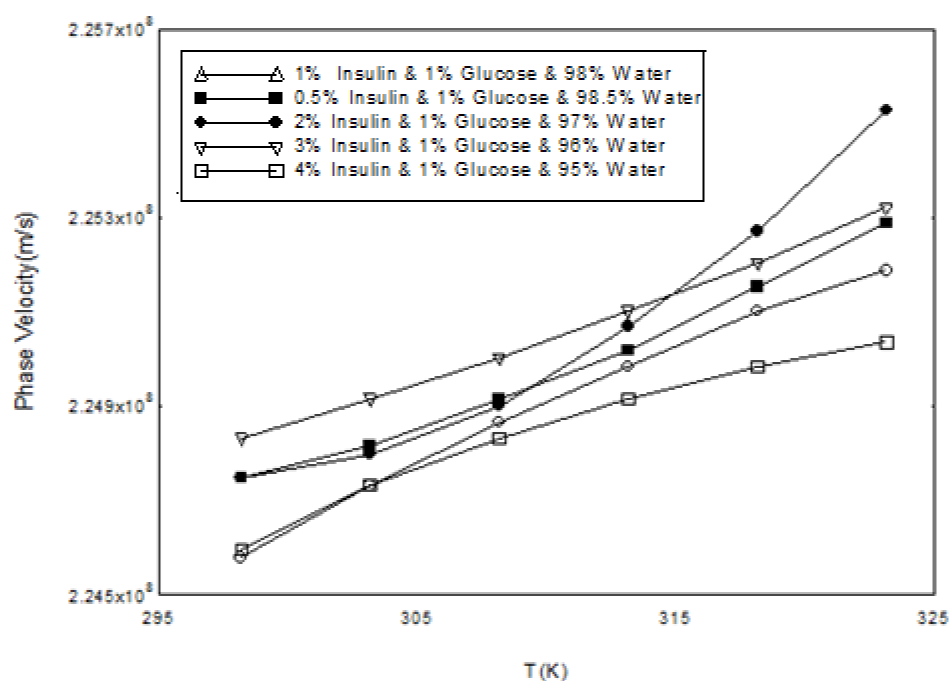


Figure (3.1.17): Phase velocity of sodium D spectral line versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

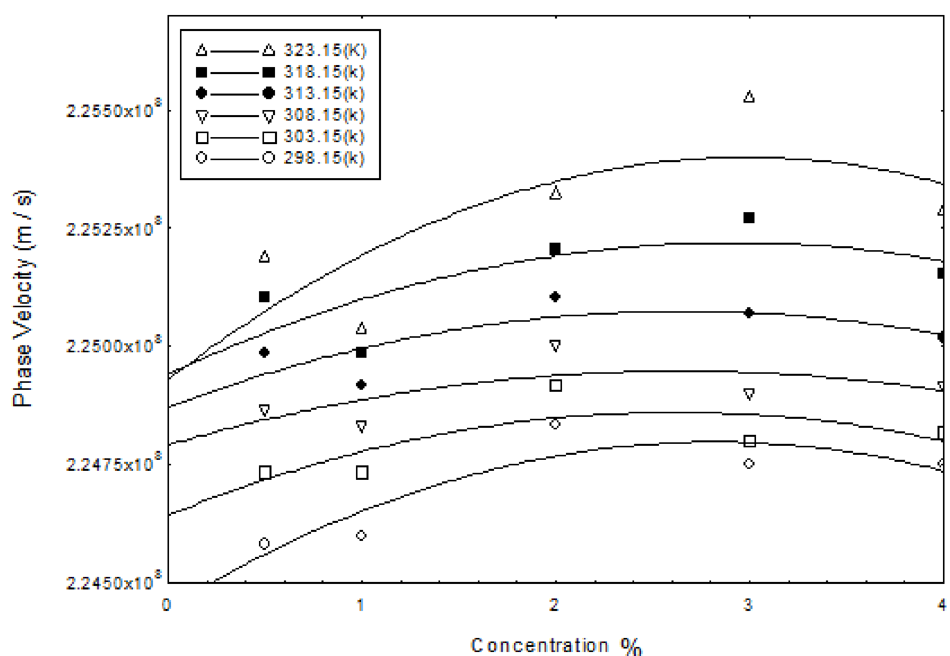


Figure (3.1.18): Phase velocity of sodium D spectral line versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

The values of calculated phase velocity of aqueous honey solutions for all concentrations and for different temperatures are ranged from 213163010.5m/s to 225272361.0m/s. While the values of calculated phase velocity of aqueous glucose solutions mixed with one gram of insulin for all concentrations and for different temperatures are ranged from 224060133.03m/s to 225424812.39m/s. Finally the values of calculated phase velocity of aqueous insulin solutions mixed with one gram of glucose for all concentrations and for different temperatures are ranged from 224580461.46m/s to 225289289.85m/s.

3.2. Thermal Gradient and Concentration Increment of Density and Specific Gravity of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

Density of substance is its mass per unit volume. The density of liquid solutions varies with temperature, concentration and pressure. Density of our samples was determined picnometrically according to official method of the association of analytical communities (AOAC) at temperatures ranging from 298.15 to 323.15^{o}K (25-50^{o}C). The accuracy of density determination was about 10^{-4} g/mL. Figures (3.2.1), (3.2.2), and (3.2.3) show the density versus temperature for all concentrations of aqueous honey and aqueous glucose and insulin solutions.

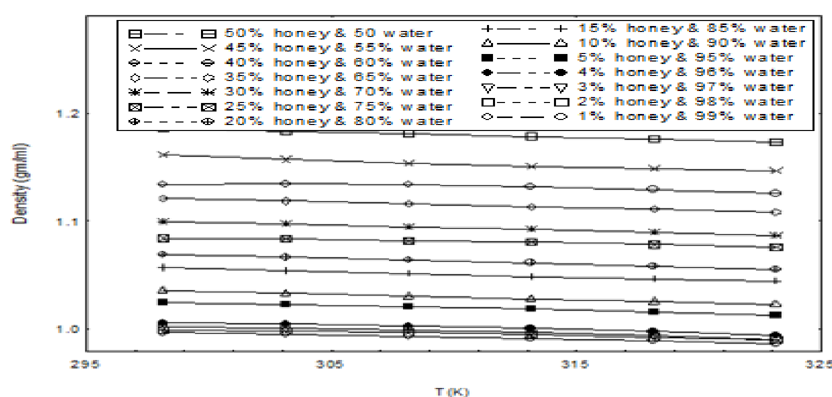


Figure (3.2.1): Densitymeasured versus temperature for different concentrations of aqueous honey solutions.

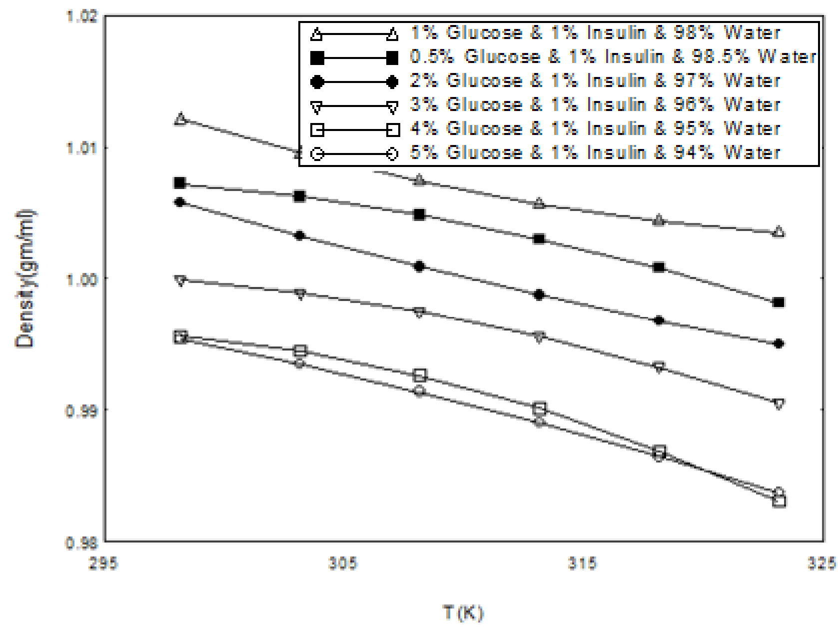


Figure (3.2.2): Densitymeasured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

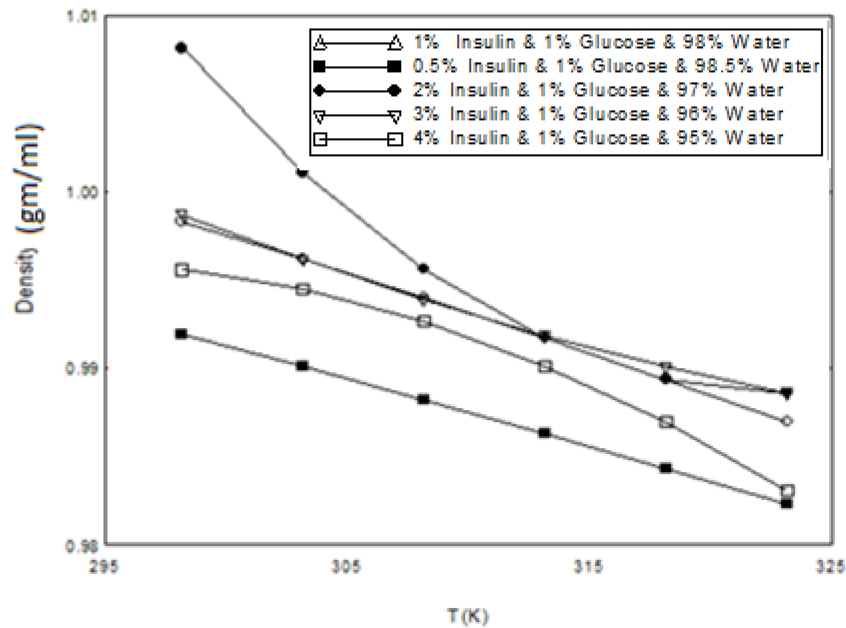


Figure (3.2.3): Densitymeasured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

Figures (3.2.4), (3.2.5), and (3.2.6) show the density versus concentration for all temperatures of aqueous honey and aqueous glucose and insulin solutions.

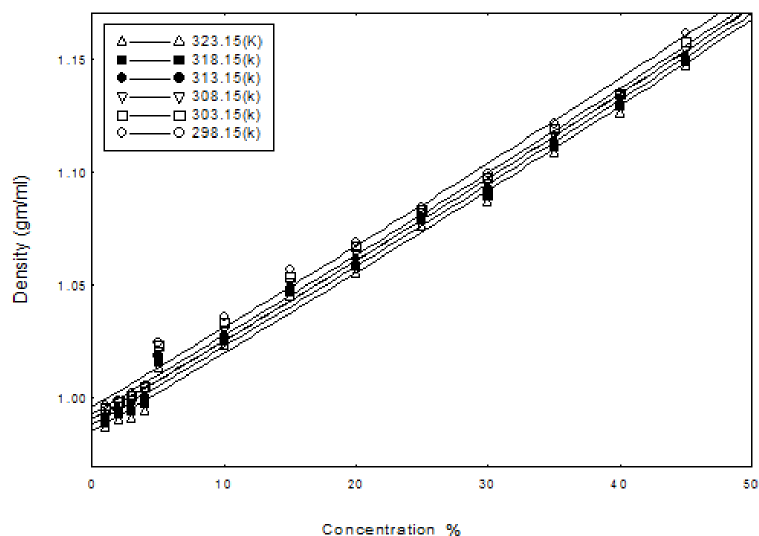


Figure (3.2.4): Densitymeasured versus concentration for different temperatures of aqueous honey solutions.

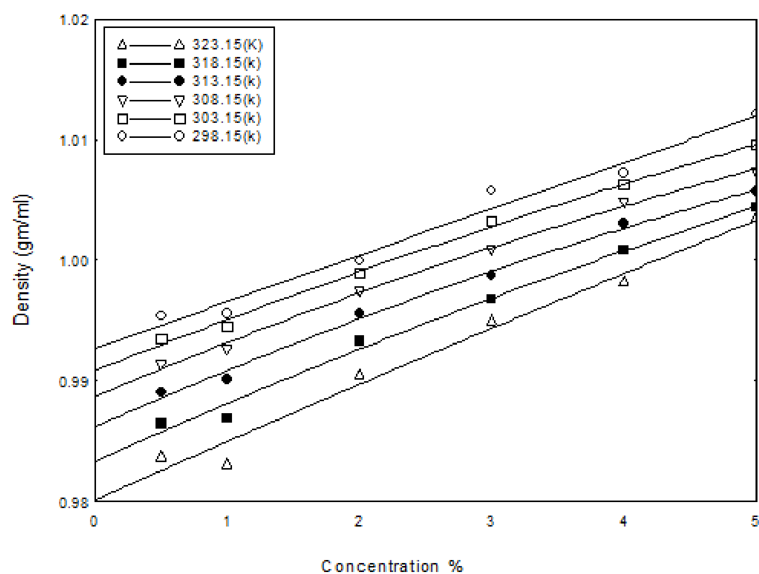


Figure (3.2.5): Densitymeasured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

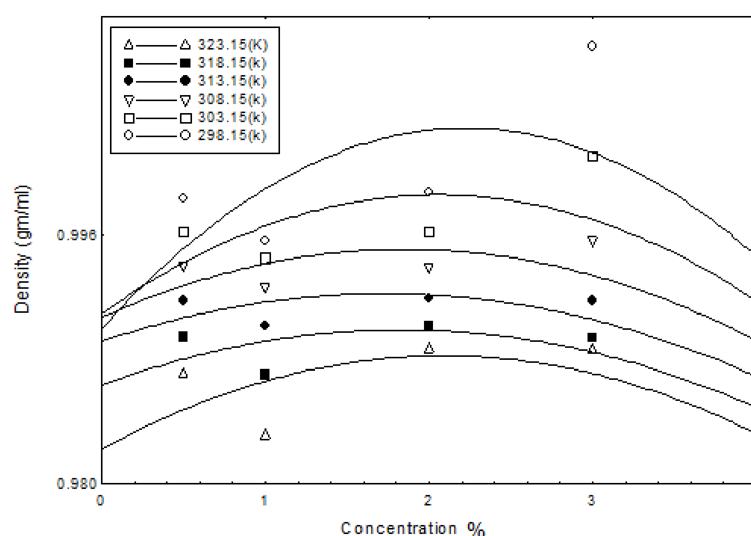


Figure (3.2.6): Densitymeasured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From Figures (3.2.1) to (3.2.4) show that the density of aqueous honey samples slightly decreases with increasing temperature, but increases with increasing honey concentration. The values of measured density of aqueous honey solutions for all concentrations and for different temperatures are ranged from 0.9867gm/ml to 1.1857gm/ml. Also from figures (3.2.4) and (3.2.5) it is noticed that the density of aqueous glucose solutions mixed with one gram of insulin increases linearly with increasing concentration and decreases with increasing temperature. The values of measured density of aqueous glucose solutions mixed with one gram of insulin for all concentrations and for different temperatures are ranged from 0.983699gm/ml to 1.01208gm/ml. Figures (3.2.3) and (3.2.6) show that the density of aqueous insulin solutions mixed with one gram of glucose decreases with increasing temperature. While the values of measured densities of aqueous insulin solutions mixed with one gram of glucose for all concentrations and for different temperatures are ranged from 0.982334gm/ml to 1.008105gm/ml. The effect of temperature on density could be accurately fitted by the polynomial equation:

$$\rho = A_{o\rho} + B_{o\rho}T + C_{o\rho}T^2 \cdots\cdots\cdots (3.2.1)$$

The fitting constants $A_{o\rho}$, $B_{o\rho}$, and $C_{o\rho}$ are given in tables (3.2.1), (3.2.2) and (3.2.3) for all concentrations of aqueous honey and aqueous glucose insulin solutions.

Table (3.2.1): The fitting constants of temperature polynomial model of density for all concentrations of aqueous honey solutions.

Concentration %	$C_{o\rho}$ (gm/ml.k^2)	$B_{o\rho}$ (gm/ml.k)	$A_{o\rho}$ (gm/ml)	R^2
1%	-4.79E-06	2.57E-03	0.65774630	1
2%	-9.77E-06	5.72E-03	0.16280423	1
3%	-1.38E-05	8.14E-03	-0.19503903	1
4%	-1.53E-05	9.02E-03	-0.32674210	1
5%	-7.23E-06	4.02E-03	0.46735952	1

Table (3.2.2): The fitting constants of temperature polynomial model of density for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	$C_{o\rho}$ (gm/ml.k^2)	$B_{o\rho}$ (gm/ml.k)	$A_{o\rho}$ (gm/ml)	R^2
0.5%	-4.E-06	0.0023	0.7115	1
1%	-1.E-05	0.0081	-0.1876	1
2%	-9.E-06	0.0051	0.2633	1
3%	4.E-06	-0.0027	1.4912	1
4%	-8.E-06	0.0048	0.3154	1
5%	8.E-06	-0.0055	1.9100	1

Table (3.2.3): The fitting constants of temperature polynomial model of density for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	$C_{o\rho}$ (gm/ml.k^2)	$B_{o\rho}$ (gm/ml.k)	$A_{o\rho}$ (gm/ml)	R^2
0.5%	-1.0E-06	0.00030	1.0089	-1.0E-06
1%	-1.4E-05	0.00800	-0.1876	-1.4E-05
2%	5.0E-06	-0.00372	1.6337	5.0E-06
3%	3.1E-05	-0.02018	4.2498	3.1E-05
4%	-1.0E-06	0.00023	1.0106	-1.0E-06

The derivativeto temperature of the previous polynomial equation gives the thermal gradient of density:

$$\frac{d\rho}{dT} = A_\rho + B_\rho T + C_\rho T^2 \cdots\cdots\cdots (3.2.2)$$

Where $A_\rho = B_{o\rho}$ and $B_\rho = 2C_{o\rho}$. The constants of the polynomial equation of temperature gradient of density for all concentrations of aqueous honey and aqueous glucose insulin solutions were shown respectively in tables (3.2.4), (3.2.5) and (3.2.6).

Table (3.2.4): The fitting constants of temperature polynomial model of temperature gradient of density for all concentrations of aqueous honey solutions.

Concentration %	A_ρ (gm/ml.k)	B_ρ (gm/ml.k^2)	C_ρ	R^2
1%	2.57E-03	-9.6E-06	0	1
2%	5.72E-03	-2E-05	0	1
3%	8.14E-03	-2.8E-05	0	1
4%	9.02E-03	-3.1E-05	0	1
5%	4.02E-03	-1.4E-05	0	1

Table (3.2.5): The fitting constants of temperature polynomial model of temperature gradient of density for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_ρ (gm/ml.k)	B_ρ (gm/ml.k^2)	C_ρ	R^2
0.5%	0.0023	-8.0E-06	0	1
1%	0.0081	-2.0E-05	0	1
2%	0.0051	-1.8E-05	0	1
3%	-0.0027	8.0E-06	0	1
4%	0.0048	-1.6E-05	0	1
5%	-0.0055	1.6E-05	0	1

Table (3.2.6): The fitting constants of temperature polynomial model of temperature gradient of density for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_ρ (gm/ml)	B_ρ (gm/ml)	C_ρ	R^2
0.5%	0.00030	-2.0E-06	0	1
1%	0.00800	-2.8E-05	0	1
2%	-0.00372	1.0E-05	0	1
3%	-0.02018	6.2E-05	0	1
4%	0.00023	-2.0E-06	0	1

While, the effect of concentration on density could be accurately fitted by the polynomial equation:

$$\rho = A_{o\rho} + B_{o\rho} C + C_{o\rho} C^2 \cdots\cdots\cdots (3.2.1)$$

The fitting constants $A_{o\rho}$, $B_{o\rho}$, and $C_{o\rho}$ are given in tables (3.2.7), (3.2.8) and (3.2.9) for all temperatures of aqueous honey and aqueous glucose insulin solutions.

Table (3.2.7): The fitting constants of concentration polynomial model of density for all temperatures of aqueous honey solutions.

T(K)	$C_{o\rho}$ (gm/ml)	$B_{o\rho}$ (gm/ml)	$A_{o\rho}$ (gm/ml)	R^2
298.15 (k)	0.0395	0.3476	0.9926	0.9926
303.15 (k)	0.0007	0.0039	0.986	0.9966
308.15 (k)	0.0007	0.0038	0.9845	0.9967
313.15 (k)	0.0007	0.0037	0.9827	0.9964
318.15 (k)	0.0007	0.0037	0.9802	0.9961
323.15 (k)	0.0007	0.0036	0.9773	0.9955

Table (3.2.8): The fitting constants of concentration polynomial model of density for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	$C_{o\rho}$ (gm/ml)	$B_{o\rho}$ (gm/ml)	$A_{o\rho}$ (gm/ml)	R^2
298.15	-0.096	0.389	0.992	0.987
303.15	-1.154	0.432	0.99	0.995
308.15	-1.725	0.463	0.998	0.996
313.15	-1.812	0.483	0.986	0.994
318.15	-1.414	0.492	0.983	0.991
323.15	-0.529	0.489	0.98	0.98

Table (3.2.9): The fitting constants of concentration polynomial model of density for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	$C_{o\rho}$ (gm/ml)	$B_{o\rho}$ (gm/ml)	$A_{o\rho}$ (gm/ml)	R^2
298.15 (k)	-128	7.34	0.903	1
303.15 (k)	-79.57	4.472	0.938	1
308.15 (k)	-45.67	2.458	0.963	1
313.15 (k)	-26.29	1.3	0.976	1
318.15 (k)	-21.44	0.999	0.978	1
323.15 (k)	-31.13	1.553	0.970	1

The derivativeto concentration of the previous polynomial equation gives the concentration increment of density:

$$\frac{d\rho}{dC} = A_\rho + B_\rho C + C_\rho C^2 \cdots\cdots\cdots \text{(3.2.2)}$$

Where $A_\rho = B_{o\rho}$ and $B_\rho = 2C_{o\rho}$. The constants of the polynomial equation of concentration increment of density for all temperatures of aqueous

honey and aqueous glucose insulin solutions were shown respectively in tables (3.2.10), (3.2.11) and (3.2.12).

Table (3.2.10): The fitting constants of concentration polynomial model of concentration increment of density for all temperatures of aqueous honey solutions.

T(K)	A_ρ (gm/ml)	B_ρ (gm/ml)		R^2
298.15 (k)	0.3476	7.9E-02	0	1
303.15 (k)	0.0039	1.4E-03	0	1
308.15 (k)	0.0038	1.4E-03	0	1
313.15 (k)	0.0037	1.4E-03	0	1
318.15 (k)	0.0037	1.4E-03	0	1
323.15 (k)	0.0036	1.4E-03	0	1

Table (3.2.11): The fitting constants of concentration polynomial model of concentration increment of density for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_ρ (gm/ml)	B_ρ (gm/ml)		R^2
298.15 (k)	0.389	-0.192	0	1
303.15 (k)	0.432	-2.308	0	1
308.15 (k)	0.463	-3.450	0	1
313.15 (k)	0.483	-3.624	0	1
318.15 (k)	0.492	-2.828	0	1
323.15 (k)	0.489	-1.058	0	1

Table (3.2.12): The fitting constants of concentration polynomial model of concentration increment of density for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_ρ (gm/ml)	B_ρ (gm/ml)		R^2
298.15 (k)	7.34	256-	0	1
303.15 (k)	4.472	159.1-	0	1
308.15 (k)	2.458	91.34-	0	1
313.15 (k)	1.3	52.58-	0	1
318.15 (k)	0.999	42.88-	0	1
323.15 (k)	1.553	62.26-	0	1

Specific gravity is the ratio of the density of a substance to the density (mass of the same unit volume) of a reference substance. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance is nearly always water at its densest, (4°C) for liquids and for gases, air at room temperature, (21°C). In this case it gave specific gravity S_G of these samples at a given temperature and given concentration using the ratio of the measured sample density ρ_S to the density of distilled water ρ_W.

$$S_G = \rho_S/\rho_W \quad \cdots\cdots\cdots (3.2.3)$$

Figures (3.2.7), (3.2.8) and (3.2.9) show the calculated values of specific gravity versus temperature for all concentrations of aqueous honey and aqueous glucose insulin solutions. While, figures (3.2.10), (3.2.11) and (3.2.12) show the calculated values of specific gravity versus concentration for all temperatures of aqueous honey and aqueous glucose insulin solutions.

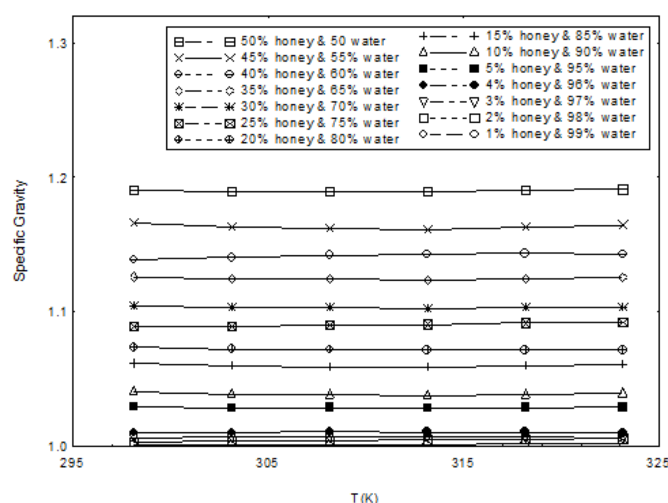


Figure (3.2.7): Specific gravity measured versus temperature for different concentrations of aqueous honey solutions.

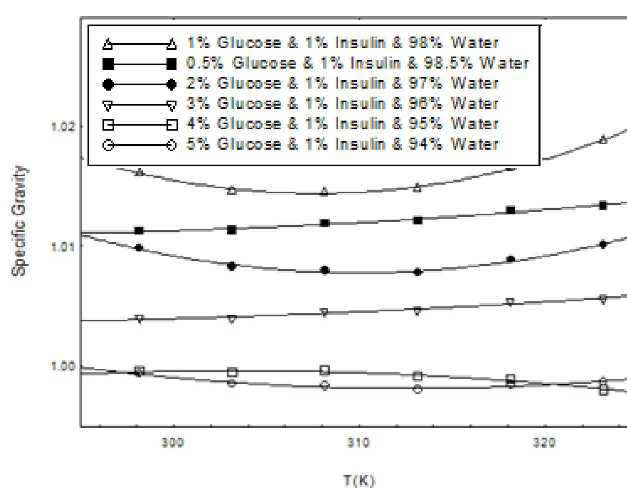


Figure (3.2.8): Specific gravity measured versus temperature for different glucose concentrations of aqueous glucose solutions mixed with one gram of insulin.

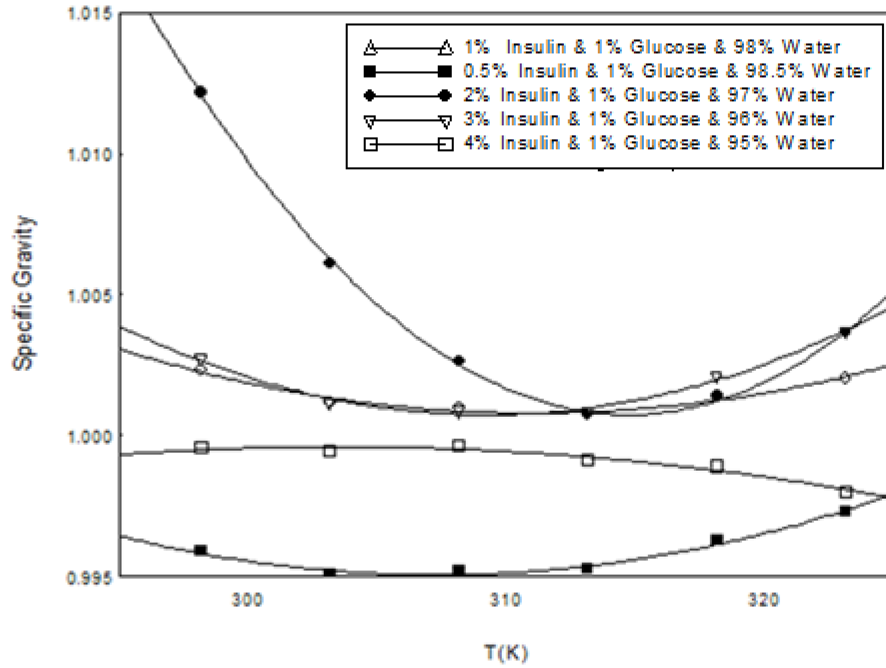


Figure (3.2.9): Specific gravity measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

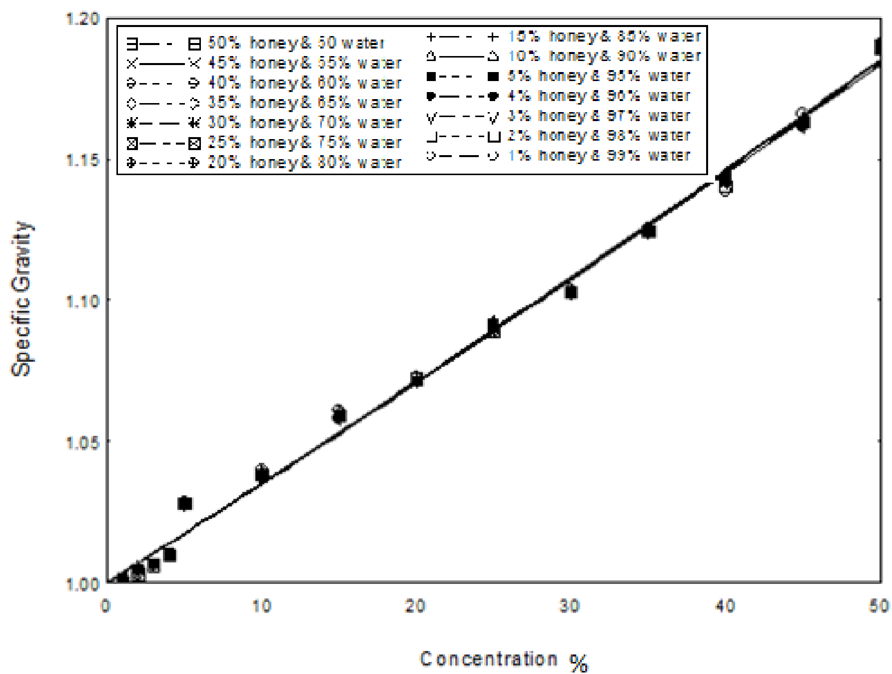


Figure (3.2.10): Specific gravity measured versus concentration for different temperatures of aqueous honey solutions.

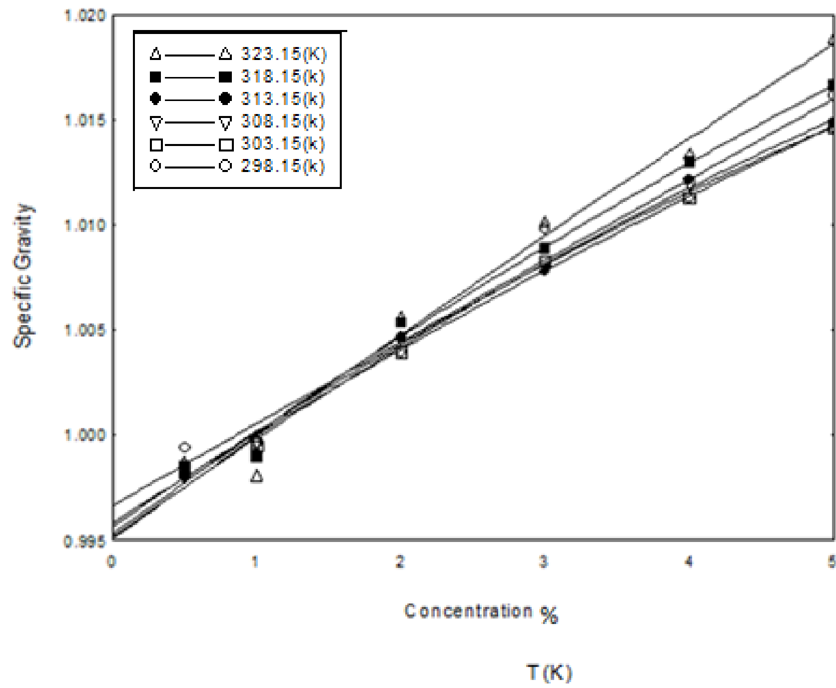


Figure (3.2.11): Specific gravity measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

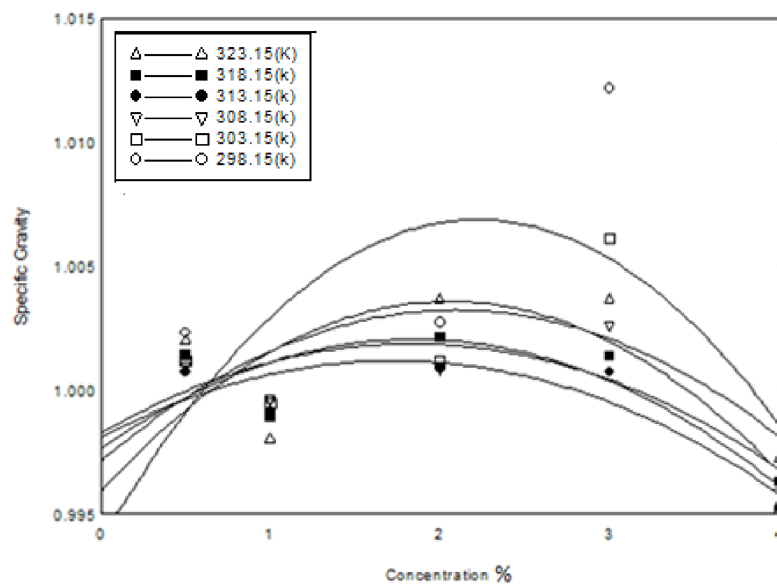


Figure (3.2.12): Specific gravity measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From figures (3.2.7-8) to (3.2.10-11) we can see that the calculated specific gravity of aqueous honey solutions and aqueous glucose solutions independent on temperature but increased with increasing corresponding concentration.

3.3. Thermal Gradient and Concentration Increment of Dynamic Viscosity and Activation Energy of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

In the food industry and pharmacology, viscosity is one of the most important parameters required in the design of technological process. On the other side, viscosity is also an important factor that determines the overall quality and stability of food system. From the physicochemical point of view, viscosity means the resistance of one part of the fluid to move relative to another one. Like most other physical properties viscosity is affected by structural parameters, temperature, concentration and pressure. Dynamic or absolute viscosity η can be obtained by multiplying the kinematic viscosity of fluid ν by its mass density (Neelamgam and Krishnaraj, 2011).

$$\eta = \rho\nu \cdots\cdots\cdots\cdots (3.3.1)$$

Dynamic viscosity is defined as the ratio of shear stress τ (force over cross section area) to the rate of deformation γ (the difference of velocity over a sheared distance), and it is presented as:

$$\eta = \frac{\tau}{du/dx} = \frac{\tau}{\gamma} \cdots\cdots\cdots\cdots (3.3.2)$$

Figures (3.3.1), (3.3.2) and (3.3.3) illustrate the measured dynamic viscosity versus temperature for all concentrations of aqueous honey and aqueous glucose insulin solutions.

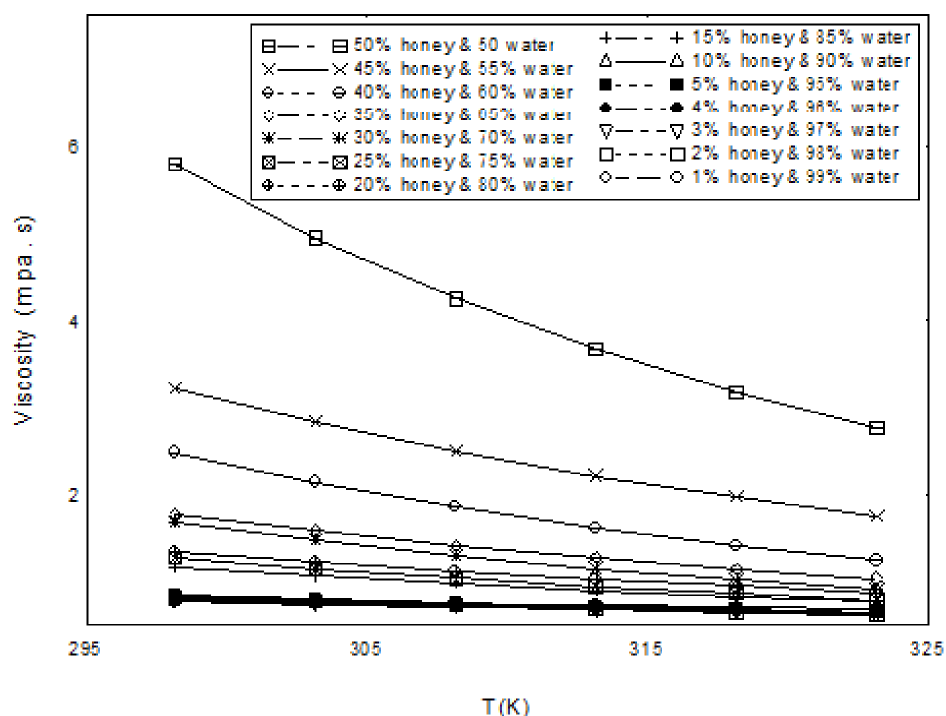


Figure (3.3.1): Dynamic viscositymeasured versus temperature for different concentrations of aqueous honey solutions.

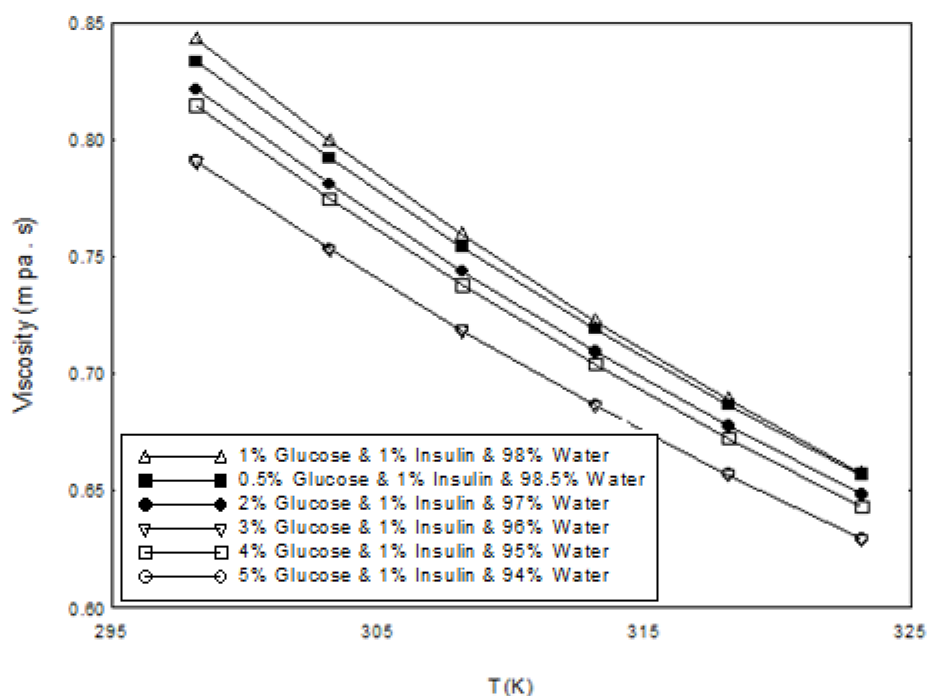


Figure (3.3.2): Dynamic viscosity measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

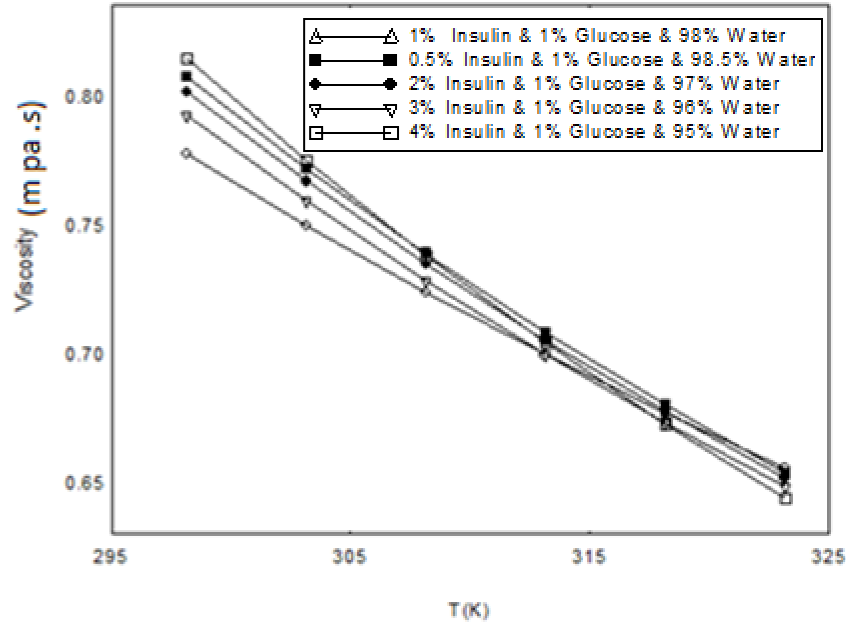


Figure (3.3.3): Dynamic viscosity measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

The values of measured dynamic viscosity of aqueous honey solutions for all concentrations and for different temperatures are ranged from 0.61439mPa.s to 5.787879mPa.s. But the values of measured dynamic viscosity of aqueous glucose solutions mixed with one gram of insulin for all concentrations and for different temperatures are ranged from 0.629398mPa.s to 0.842479mPa.s.Finally the values of measured dynamic viscosity of aqueous insulin solutions mixed with one gram of glucose for all concentrations and for different temperatures are ranged from 0.655088mPa.s to 0.807458mPa.s.

The dynamic viscosities versus concentration in the temperature are ranged from298.15 to 323.15^{o}K (25-50^{o}C) of aqueous honey and aqueous glucose insulin solutions were shown respectively in figures (3.3.4), (3.3.5) and (3.3.6).

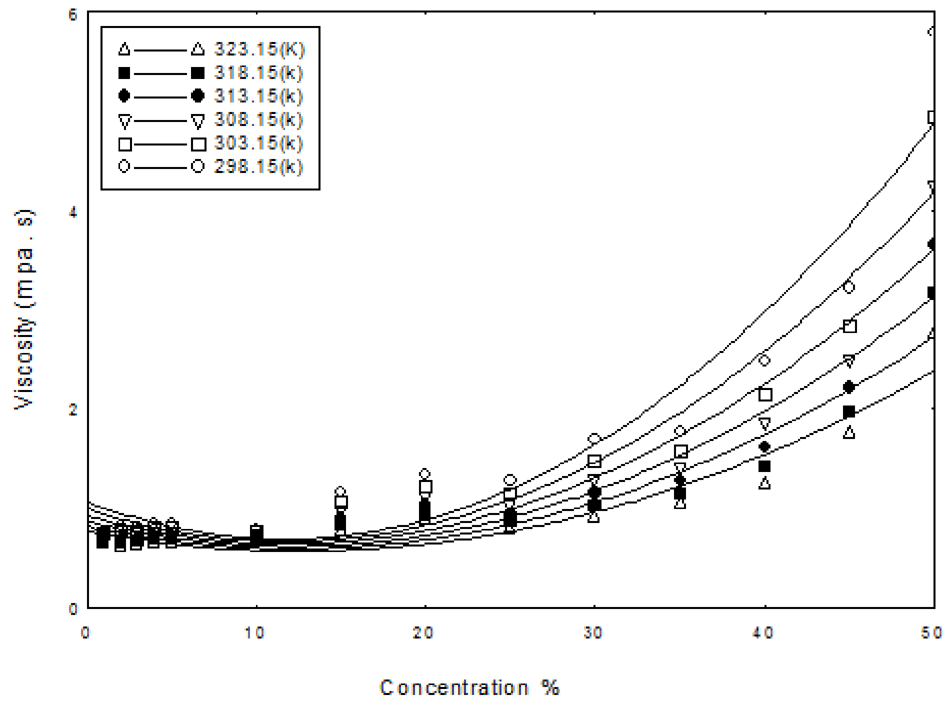


Figure (3.3.4): Dynamic viscosity measured versus concentration for different temperatures of aqueous honey solutions.

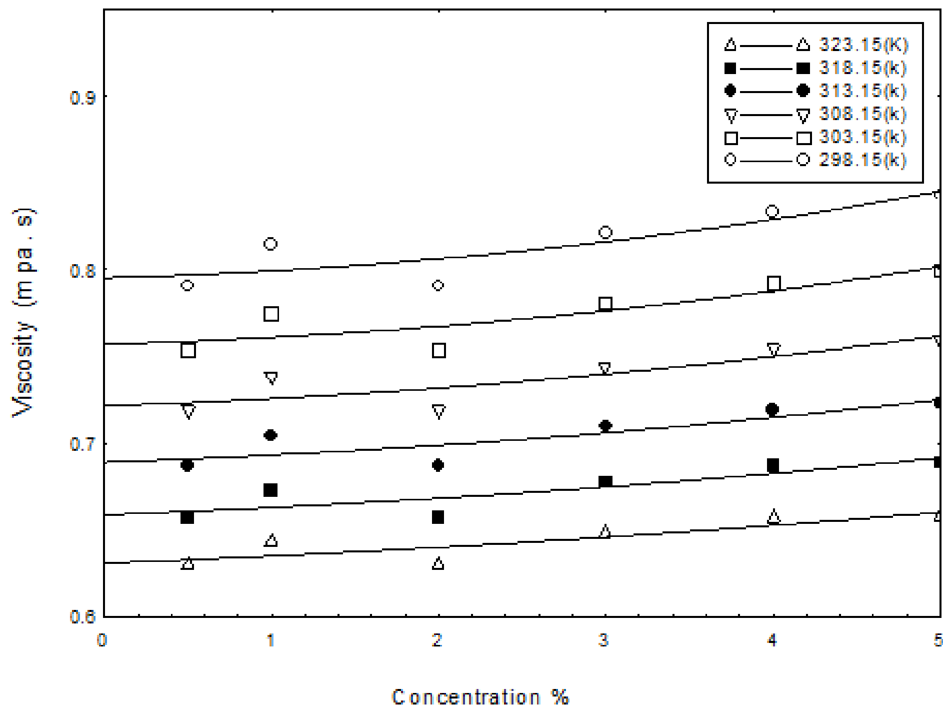


Figure (3.3.5): Dynamic viscosity measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

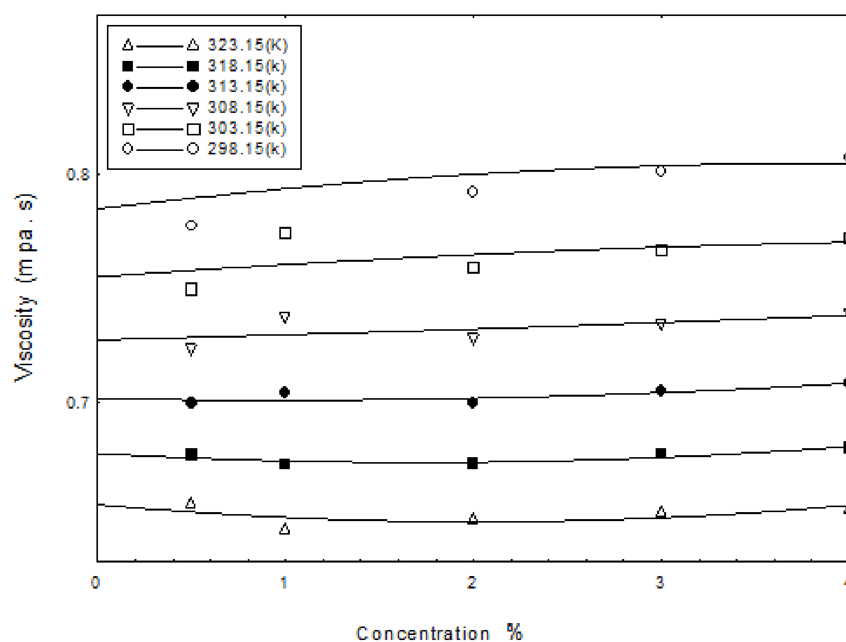


Figure (3.3.5): Dynamic viscosity measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From figures (3.3.1) to (3.3.4) they showed that the dynamic viscosity of aqueous honey samples increases with increasing concentration and with decreasing temperature. But from figures (3.3.2) and (3.3.5) it is noticed that the dynamic viscosity of aqueous glucose solutions mixed with one gram of insulin linearly increases with increasing glucose concentration and decreases with increasing temperature. While, figures (3.3.3) and (3.3.6) show that the dynamic viscosity of aqueous insulin solutions mixed with one gram of glucose remains approximately constant with increasing insulin concentration and decreases with increasing temperature. The effect of temperature on dynamic viscosity could be accurately fitted by the polynomial equation:

$$\eta = A_{o\eta} + B_{o\eta} T + C_{o\eta} T^2 \cdots\cdots\cdots \text{(3.3.3)}$$

The fitting constants $A_{o\eta}$, $B_{o\eta}$, and $C_{o\eta}$ are given in tables (3.3.1), (3.3.2) and (3.3.3) for all concentrations of aqueous honey and aqueous glucose insulin solutions.

Table (3.3.1): The fitting constants of temperature polynomial model of dynamic viscosity for all concentrations of aqueous honey solutions.

Concentration %	$C_{o\eta}$ (m pa . s . k^{-2})	$B_{o\eta}$ (m pa . s . k^{-1})	$A_{o\eta}$ (m pa . s)	R^2
1%	4.00E-05	-0.0281	5.8779	0.98865828
2%	7.00E-05	-0.0549	10.52	0.96081104
3%	6.00E-05	-0.0418	8.2853	0.98199090
4%	6.00E-05	-0.0498	9.6965	0.78488972
5%	6.00E-05	-0.0447	8.8246	0.95637700

Table (3.3.2): The fitting constants of temperature polynomial model of dynamic viscosity for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	$C_{o\eta}$ (m pa . s . k^{-2})	$B_{o\eta}$ (m pa . s . k^{-1})	$A_{o\eta}$ (m pa . s)	R^2
0.5%	5.E-05	-0.0375	7.534	1
1%	5.E-05	-0.0405	8.0709	1
2%	5.E-05	-0.0375	7.534	1
3%	5.E-05	-0.041	8.1584	1
4%	6.E-05	-0.0419	8.3446	1
5%	6.E-05	-0.0449	8.8663	1

Table (3.3.3): The fitting constants of temperature polynomial model of dynamic viscosity for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	$C_{o\eta}$ (m pa . s . k^{-2})	$B_{o\eta}$ (m pa . s . k^{-1})	$A_{o\eta}$ (m pa . s)	R^2
0.5%	3.2E-05	-0.02504	5.3598	1
1%	5.4E-05	-0.04049	8.0709	1
2%	4.2E-05	-0.03162	6.5188	1
3%	4.4E-05	-0.0334	6.8381	1
4%	4.6E-05	-0.03474	7.0772	1

It can be easy to compare between the effect of temperature and concentration on dynamic viscosity by calculating of thermal gradients $d\eta/dT$ and concentration increments $d\eta/dC$ of dynamic viscosity. The

derivative to temperature of the previous polynomial equation gives the thermal gradient of dynamic viscosity:

$$\frac{d\eta}{dT} = A_\eta + B_\eta T + C_\eta T^2 \cdots\cdots\cdots (3.3.4)$$

Where $A_\eta = B_{o\eta}$ and $B_\eta = 2C_{o\eta}$. The constants of the polynomial equation of temperature gradient of dynamic viscosity for all concentrations of aqueous honey and aqueous glucose insulin solutions were shown respectively in tables (3.3.4), (3.3.5) and (3.3.6).

Table (3.3.4): The fitting constants of temperature polynomial model of temperature gradient of dynamic viscosity for all concentrations of aqueous honey solutions.

Concentration %	A_η (m pa . s . k^{-1})	B_η (m pa . s . k^{-2})		R^2
1%	-0.0281	6.4E-05	0	0.98865828
2%	-0.0549	1.1E-04	0	0.96081104
3%	-0.0418	8.4E-05	0	0.98199090
4%	-0.0498	8.8E-05	0	0.78488972
5%	-0.0447	9.2E-05	0	0.95637700

Table (3.3.5): The fitting constants of temperature polynomial model of temperature gradient of dynamic viscosity for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_η (m pa . s . k^{-1})	B_η (m pa . s . k^{-2})		R^2
0.5%	-3.7E-02	2.0E-04	0	1
1%	-4.0E-02	2.0E-04	0	1
2%	-3.7E-02	2.0E-04	0	1
3%	-4.1E-02	2.0E-04	0	1
4%	-4.1E-02	2.4E-04	0	1
5%	-4.5E-02	2.4E-04	0	1

Table (3.3.6): The fitting constants of temperature polynomial model of temperature gradient of dynamic viscosity for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_η (m pa . s . k^{-1})	B_η (m pa . s . k^{-2})		R^2
0.5%	-2.5E-02	6.00E-05	0	1
1%	-4.0E-02	1.08E-04	0	1
2%	-3.2E-02	8.40E-05	0	1
3%	-3.2E-02	8.80E-05	0	1
4%	-3.2E-02	9.20E-05	0	1

The effect of concentration on dynamic viscosity could be accurately fitted by the polynomial equation:

$$\eta = A_{o\eta} + B_{o\eta} C + C_{o\eta} C^2 \cdots\cdots\cdots \quad (3.3.5)$$

The fitting constants $A_{o\eta}$, $B_{o\eta}$, and $C_{o\eta}$ are given in tables (3.3.7), (3.3.8) and (3.3.9) for all temperatures of aqueous honey and aqueous glucose insulin solutions.

Table (3.3.7): The fitting constants of concentration polynomial model of dynamic viscosity for all temperatures of aqueous honey solutions.

T(K)	$C_{o\eta}$ (m pa . s)	$B_{o\eta}$ (m pa . s)	$A_{o\eta}$ (m pa . s)	R^2
298.15 (k)	0.0466	-0.4375	1.5888	0.8767
303.15 (k)	0.0392	-0.3688	1.4278	0.8765
308.15 (k)	0.0331	-0.3127	1.2926	0.8752
313.15 (k)	0.0281	-0.2667	1.1783	0.8726
318.15 (k)	0.0240	-0.2288	1.081	0.8683
323.15 (k)	0.0205	-0.1974	0.9976	0.8621

Table (3.3.8): The fitting constants of concentration polynomial model of dynamic viscosity for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	$C_{o\eta}$ (m pa . s)	$B_{o\eta}$ (m pa . s)	$A_{o\eta}$ (m pa . s)	R^2
298.15	15.13	0.237	0.795	0.758
303.15	12.40	0.274	0.756	0.751
308.15	9.983	0.307	0.721	0.744
313.15	7.841	0.334	0.688	0.736
318.15	5.940	0.357	0.658	0.726
323.15	4.249	0.377	0.63	0.715

Table (3.3.9): The fitting constants of concentration polynomial model of dynamic viscosity for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	$C_{o\eta}$ (m pa . s)	$B_{o\eta}$ (m pa . s)	$A_{o\eta}$ (m pa . s)	R^2
298.15 (k)	-15.75	1.717	0.764	1
303.15 (k)	-13.85	1.477	0.734	1
308.15 (k)	-12.14	1.261	0.707	1
313.15 (k)	-10.58	1.066	0.682	1
318.15 (k)	-9.15	0.889	0.658	1
323.15 (k)	-7.87	0.730	0.636	1

The derivative to concentration of the previous polynomial equation

gives the concentration increment of dynamic viscosity:

$$\frac{d\eta}{dC} = A_\eta + B_\eta C + C_\eta C^2 \cdots\cdots\cdots (3.3.6)$$

Where $A_\eta = B_{o\eta}$ and $B_\eta = 2C_{o\eta}$. The constants of the polynomial equation of concentration increment of dynamic viscosity for all temperatures of aqueous honey and aqueous glucose insulin solutions were shown

Respectively in tables (3.3.10), (3.3.11) and (3.3.12).

Table (3.3.10): The fitting constants of concentration polynomial model of concentration increment of dynamic viscosity for all temperatures of aqueous honey solutions.

T(K)	A_η (m pa . s)	B_η (m pa . s)		R^2
298.15 (k)	-0.4375	0.093	0	1
303.15 (k)	-0.3688	0.078	0	1
308.15 (k)	-0.3127	0.066	0	1
313.15 (k)	-0.2667	0.056	0	1
318.15 (k)	-0.2288	0.048	0	1
323.15 (k)	-0.1974	0.041	0	1

Table (3.3.11): The fitting constants of concentration polynomial model of concentration increment of dynamic viscosity for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_η (m pa . s)	B_η (m pa . s)	C	R^2
298.15 (k)	0.237	30.26	0	1
303.15 (k)	0.274	24.8	0	1
308.15 (k)	0.307	19.97	0	1
313.15 (k)	0.334	15.68	0	1
318.15 (k)	0.357	11.88	0	1
323.15 (k)	0.377	8.498	0	1

Table (3.3.12): The fitting constants of concentration polynomial model of concentration increment of dynamic viscosity for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_η (m pa . s)	B_η (m pa . s)	C	R^2
298.15 (k)	1.717	-31.5	0	1
303.15 (k)	1.477	-27.7	0	1
308.15 (k)	1.261	-24.28	0	1
313.15 (k)	1.066	-21.16	0	1
318.15 (k)	0.889	-18.3	0	1
323.15 (k)	0.730	-15.74	0	1

The effect of temperature on dynamic viscosity can be used to calculate the activation energy of the viscous flow of pure, liquid mixtures and liquid solutions by FrenkelEyring equation (FEE) (Tipvarakarnkoon*et al.*, 2008). The activation energy controls the rate of molecular motion and therefore the flow of liquids; consequently, viscosity can be considered as a thermally activated process whose temperature dependence is given by the following empirical Arrhenius equation:

$$\eta = Aexp\left[\frac{-\Delta G}{RT}\right] \cdots\cdots\cdots (3.3.7)$$

Where ΔG is the activation energy, R is the ideal gas constant, T is the absolute temperature and A is a constant (Rubalya*et al.*, 2013). Figures

(3.3.7), (3.3.8) and (3.3.9) show the calculated activation energy for all concentrations of aqueous honey and aqueous glucose insulin solutions.

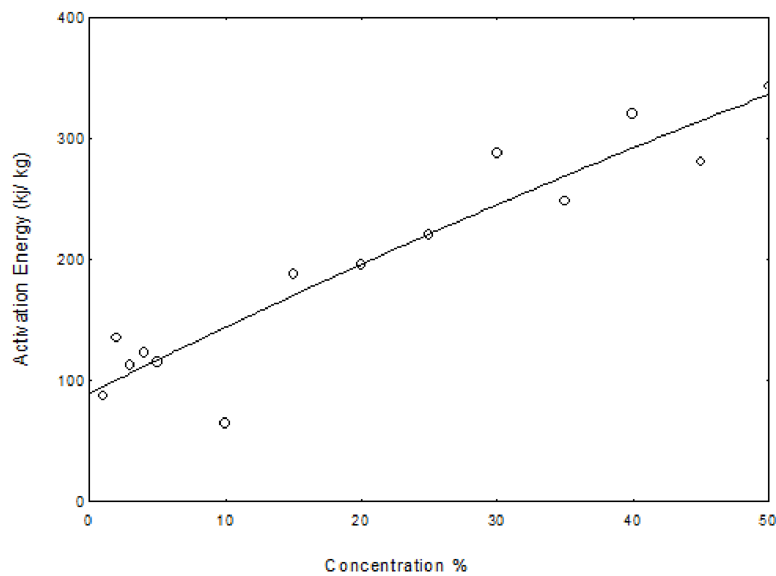


Figure (3.3.7): Activation energy measured versus concentration for different temperatures of aqueous honey solutions.

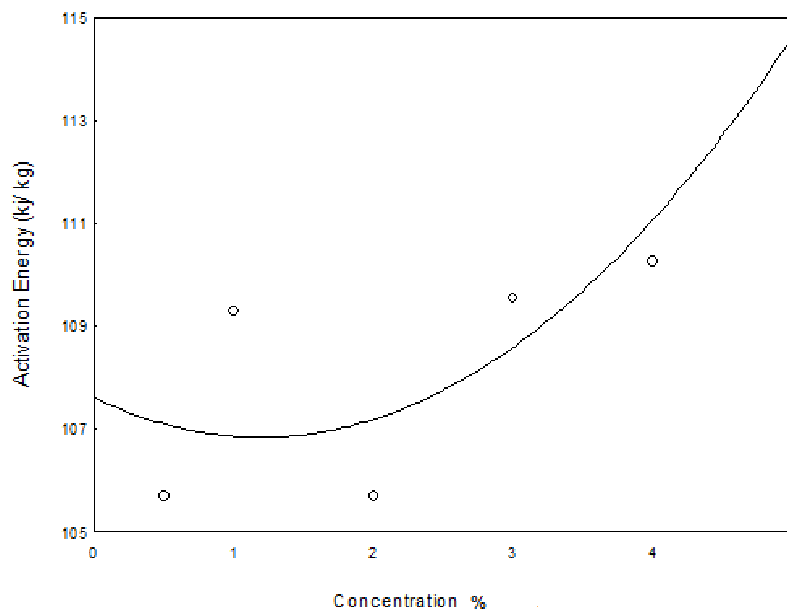


Figure (3.3.8): Activation energy measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

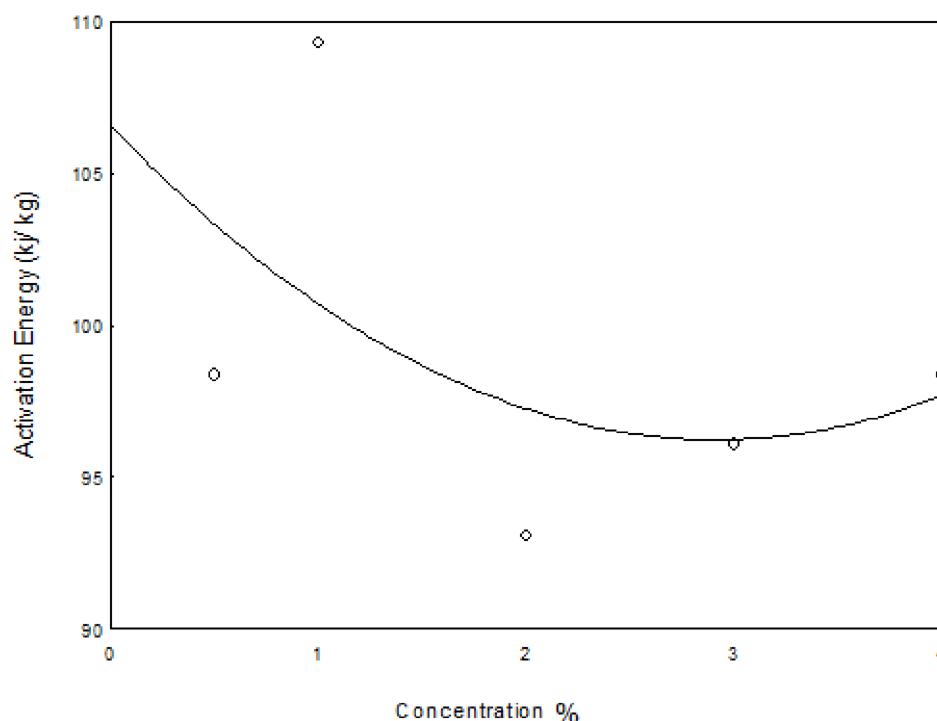


Figure (3.3.9): Activation energy measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From previous figures (3.3.7), (3.3.8) and (3.3.9) it is noticed that the activation energy increases with increasing concentration of honey and glucose while, decreases with increasing insulin concentration. The values of calculated activation energy of aqueous honey solutions for all concentrations are ranged from $63.9 kJkg^{-1}$ to $343.1 kJkg^{-1}$. But the values of calculated activation energy of aqueous glucose solutions mixed with one gram of insulin for all concentrations ranged from $105.7 kJkg^{-1}$ to $115.0 kJkg^{-1}$.Finally the values of calculated activation energy of aqueous insulin solutions mixed with one gram of glucose for all concentrations ranged from $93.1 kJkg^{-1}$ to $109.3 kJkg^{-1}$.

3.4. Specific Refraction of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures Using Classic Empirical and Semi Empirical Equations of Mixing Rules

From Maxwell's electromagnetic theory, and the wave theory of light, it was found that the specific refraction is a constant quantity for a substance with refractive index n and density ρ. The specific refraction is

fairly constant and independent of temperature. Moreover, it is applicable to any phase of the substance. Specific refraction has a several mathematical forms and it can be calculated from many mixing rule equations. In this study it calculates the specific of refraction by using the following mixing rule equations:

The specific refraction $R_{LL}$is calculated from Lorentz Lorenz equation (Deosarkar*et al.*, 2013; Vuksanovic*et al.*, 2014):

$$R_{LL} = \frac{(n_D^2 - 1)}{(n_D^2 + 2)} \times \frac{1}{\rho} \cdots\cdots\cdots\; (3.4.1)$$

The specific refraction $R_{GD}$is calculated from Gladstone Dale relation (Young and Finn, 1940; Vuksanovic*et al.*, 2014):

$$R_{GD} = (n_D - 1) \times \frac{1}{\rho} \cdots\cdots\cdots\; (3.4.2)$$

The specific refraction $R_{EY}$is calculated from Eykmanrelation (Young and Finn, 1940; Vuksanovic*et al.*, 2014):

$$R_{EY} = \frac{(n_D^2 - 1)}{(n_D + 0.4)} \times \frac{1}{\rho} \cdots\cdots\cdots\; (3.4.3)$$

The specific refraction $R_N$is calculated from Newton equation (Young and Finn, 1940; Vuksanovic*et al.*, 2014):

$$R_N = (n_D^2 - 1) \times \frac{1}{\rho} \cdots\cdots\cdots\; (3.4.4)$$

The specific refraction $R_{OS}$is calculated from Oster relation (Vuksanovic*et al.*, 2014):

$$R_{OS} = \frac{(n_D^2 - 1)(2n_D^2 + 1)}{n_D^2} \times \frac{1}{\rho} \cdots\cdots\cdots\; (3.4.5)$$

The specific refraction $R_{AB}$is calculated from AragoBiotequation (Vuksanovic*et al.*, 2014):

$$R_{AB} = n_D \times \frac{1}{\rho} \cdots\cdots\cdots (3.4.6)$$

The value of specific refraction is calculated by Lorentz Lorenz mixing rule equationand is directly proportional depending on electric polarizability and on thermal expansion (Khodier, 2002). The specific refractivity reflects the changes in the properties of the ions due to polarization or deformation of their electron shells under the influence of the electric field of neighboring ions. The specific of refraction of any liquid organic substance is the sum of the specific of refractions of its individual components (Lee *et al.*, 2005).

Figures (3.4.1-18) show the specific of refraction versus temperature for all concentrations of aqueous honey and aqueous glucose insulin solutionsby using the mixing rule models of Lorentz Lorenz, Gladstone Dale, Eykman, Newton, Oster and AragoBiot. While, Figures (3.4.19-36) show the specific of refraction versus concentration for all temperatures of aqueous honey and aqueous glucose insulin solutions by using the mixing rule models of Lorentz Lorenz, Gladstone Dale, Eykman, Newton, Oster and AragoBiot.

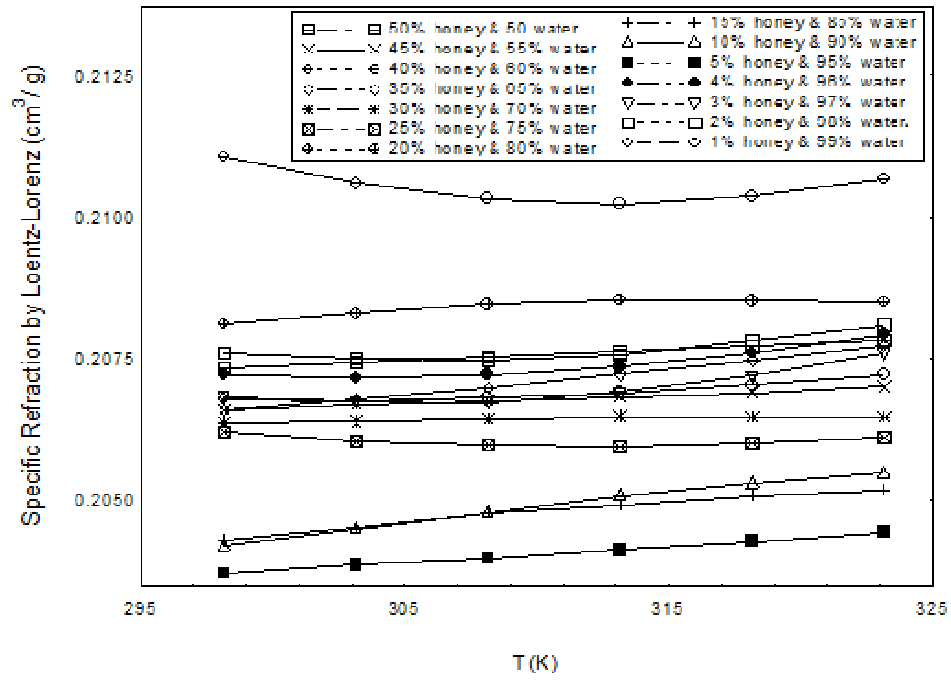


Figure (3.4.1): Specific refraction R_{LL}measured versus temperature for different concentrations of aqueous honey solutions.

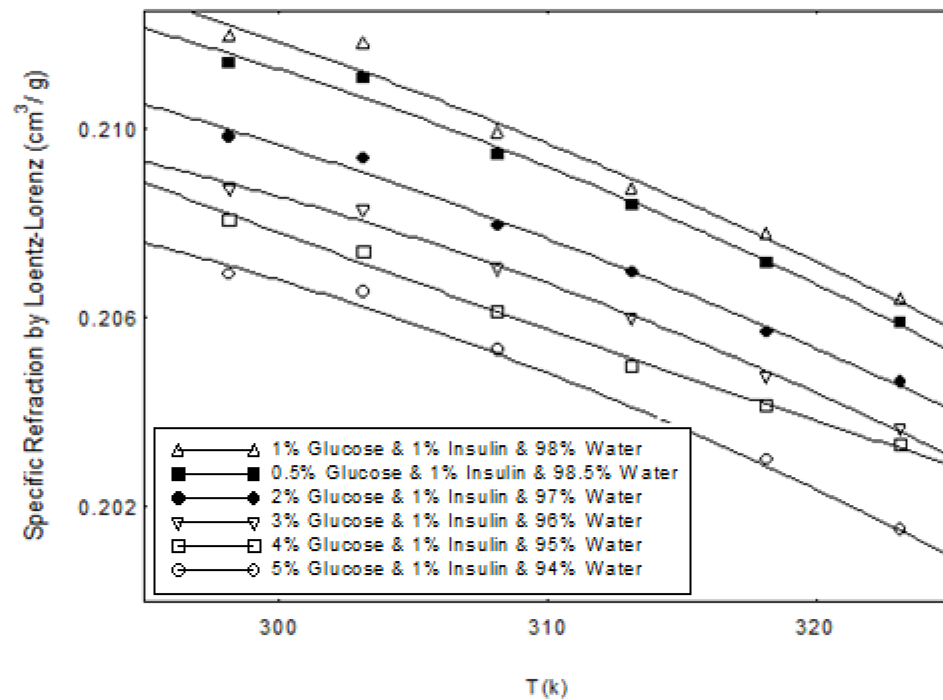


Figure (3.4.2): Specific refraction R_{LL}measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

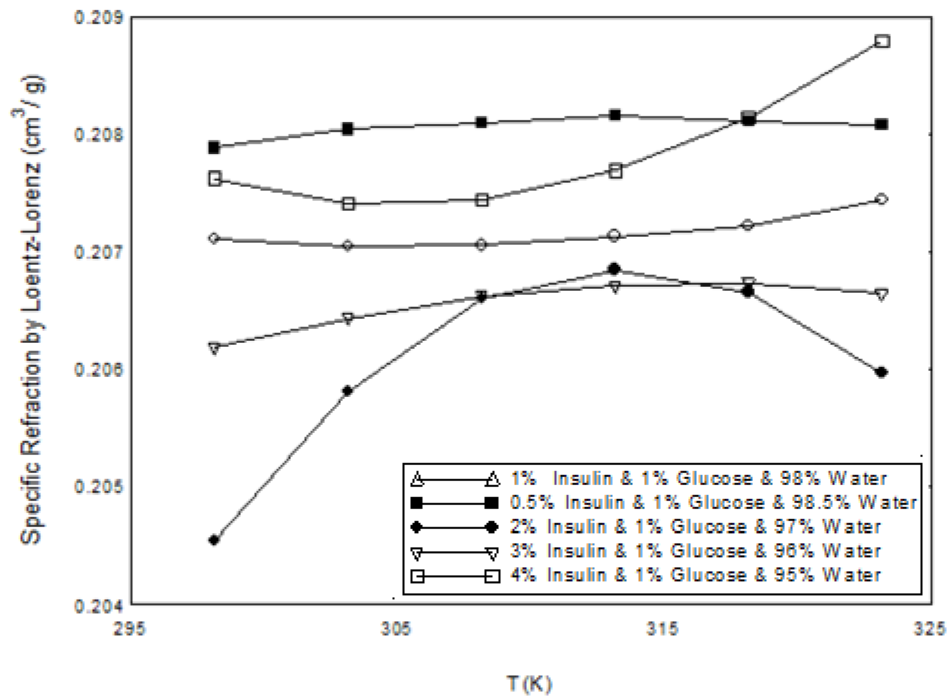


Figure (3.4.3): Specific refraction R_{LL}measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

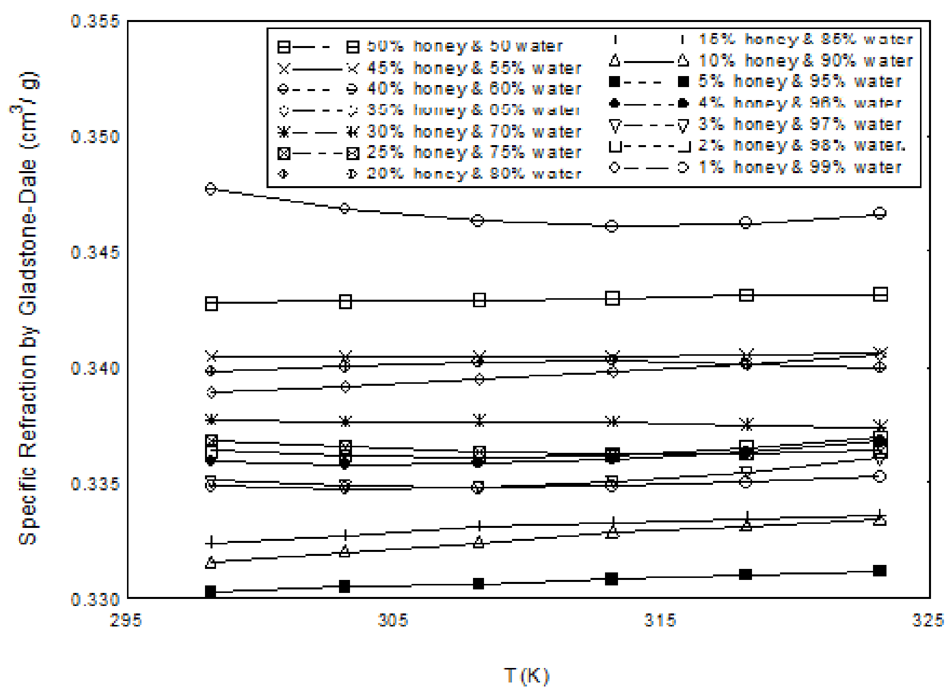


Figure (3.4.4): Specific refraction R_{GD}measured versus temperature for different concentrations of aqueous honey solutions.

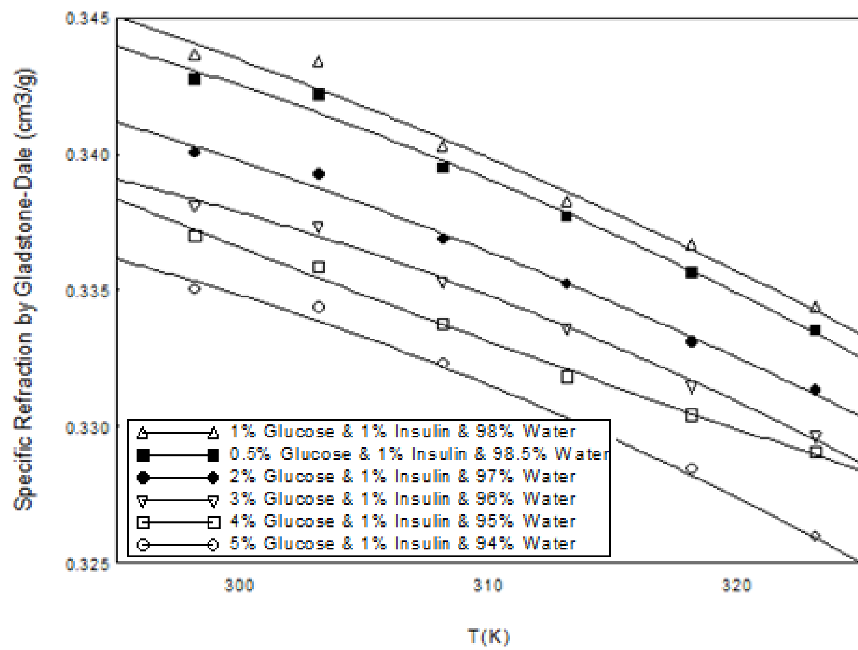


Figure (3.4.5): Specific refraction R_{GD}measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

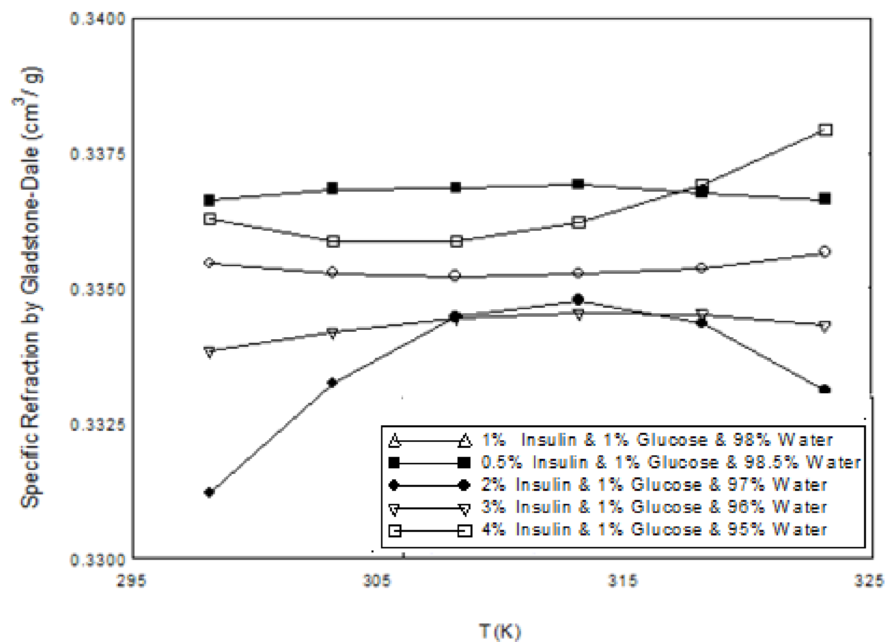


Figure (3.4.6): Specific refraction R_{GD}measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

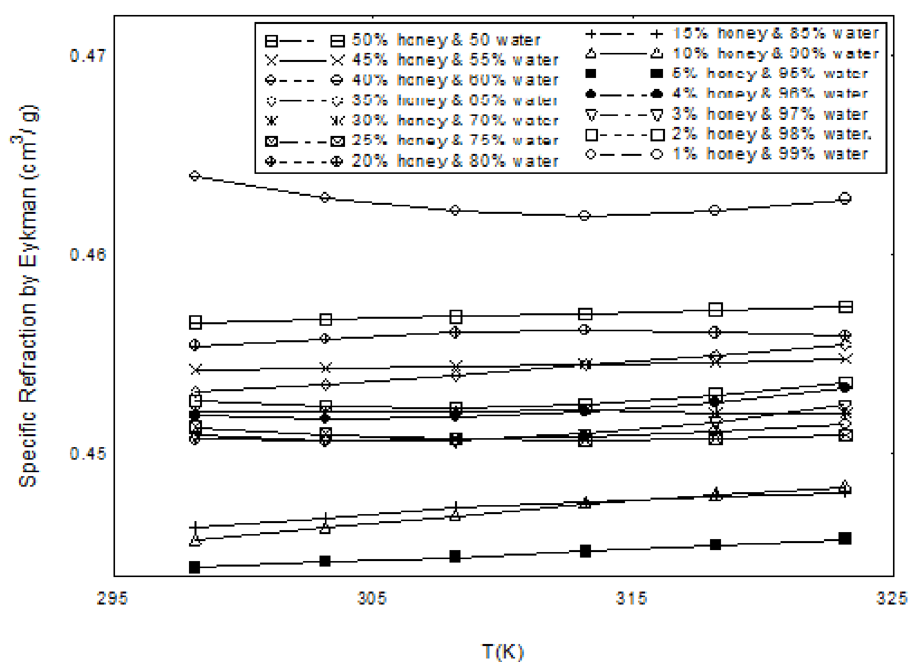


Figure (3.4.7): Specific refraction R_{EY}measured versus temperature for different concentrations of aqueous honey solutions.

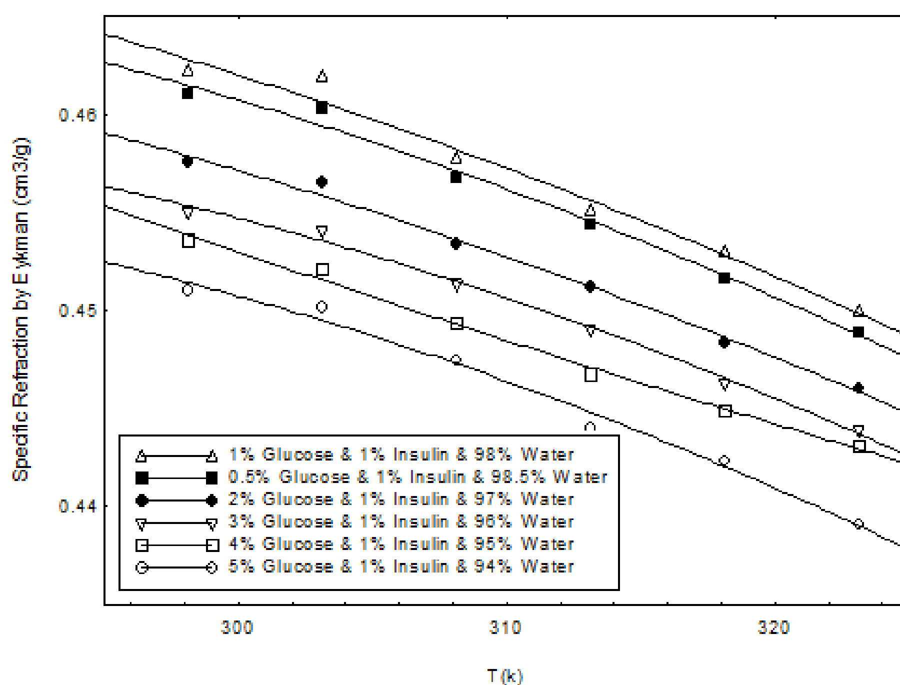


Figure (3.4.8): Specific refraction R_{EY}measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

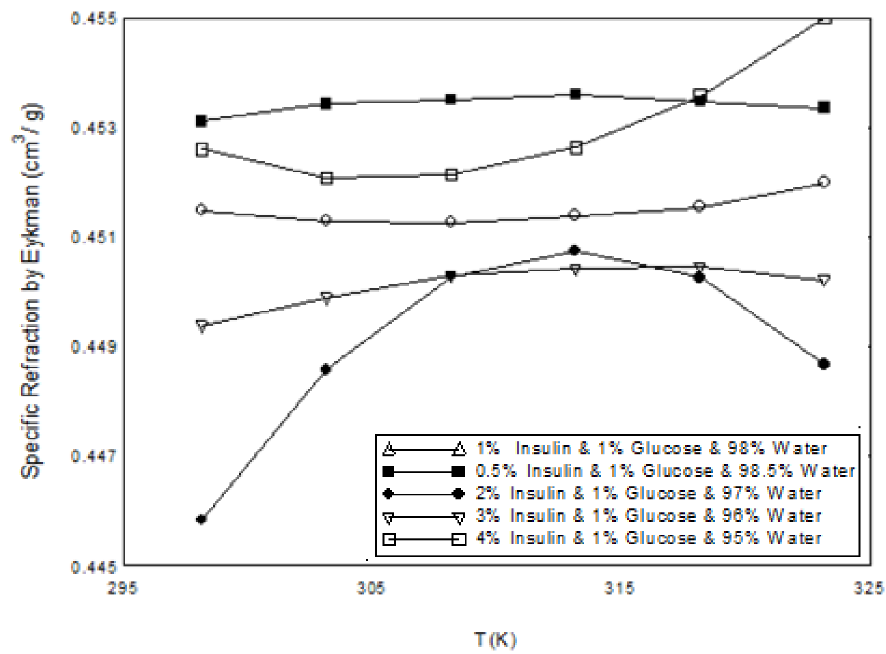


Figure (3.4.9): Specific refraction R_{EY}measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

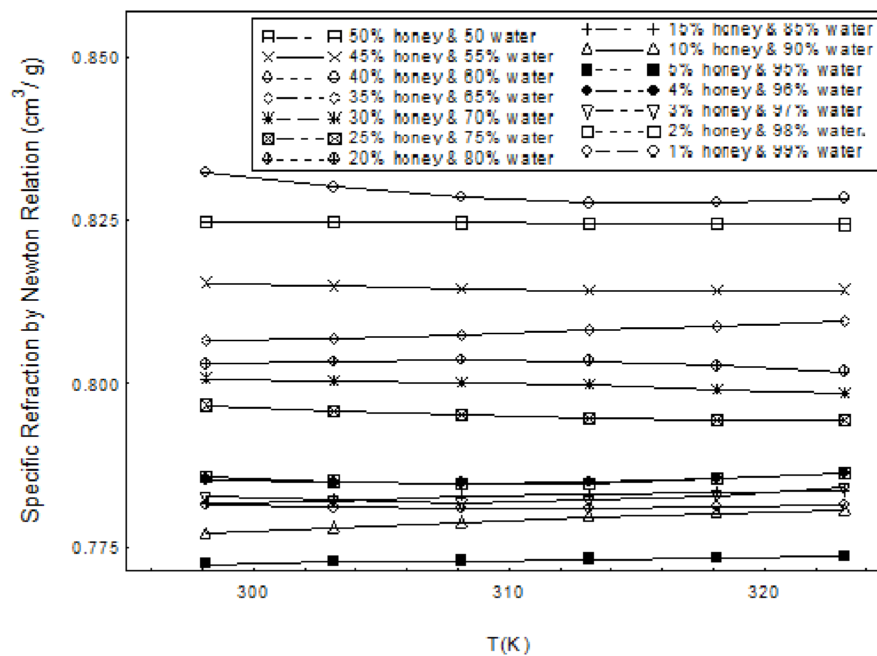


Figure (3.4.10): Specific refraction $R_N$measured versus temperature for different concentrations of aqueous honey solutions.

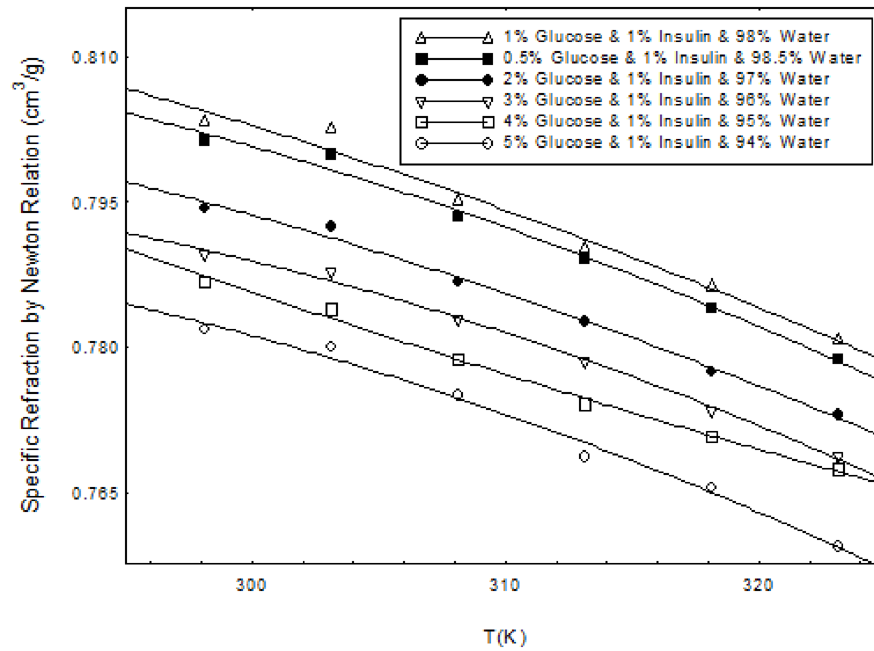


Figure (3.4.11): Specific refraction $R_N$measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

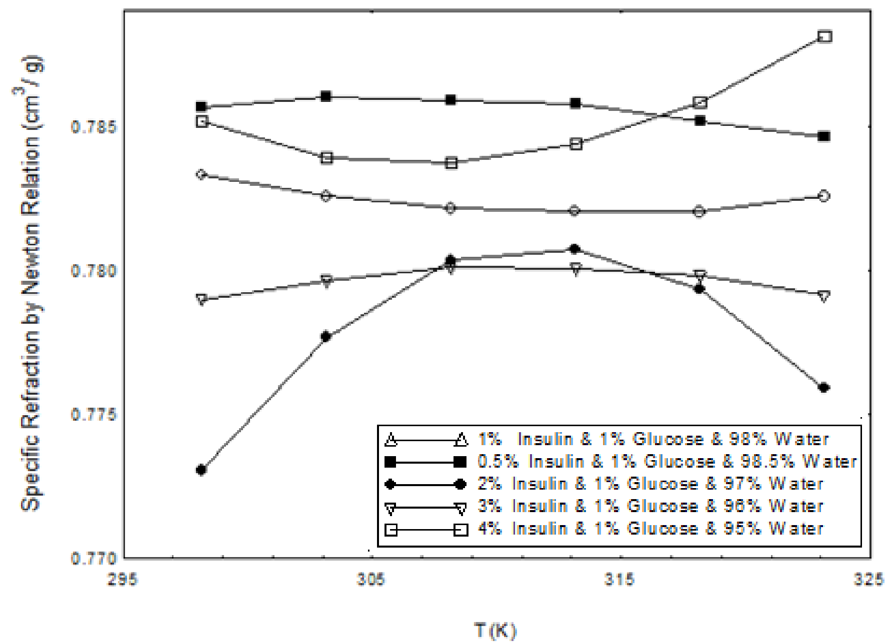


Figure (3.4.12): Specific refraction $R_N$measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

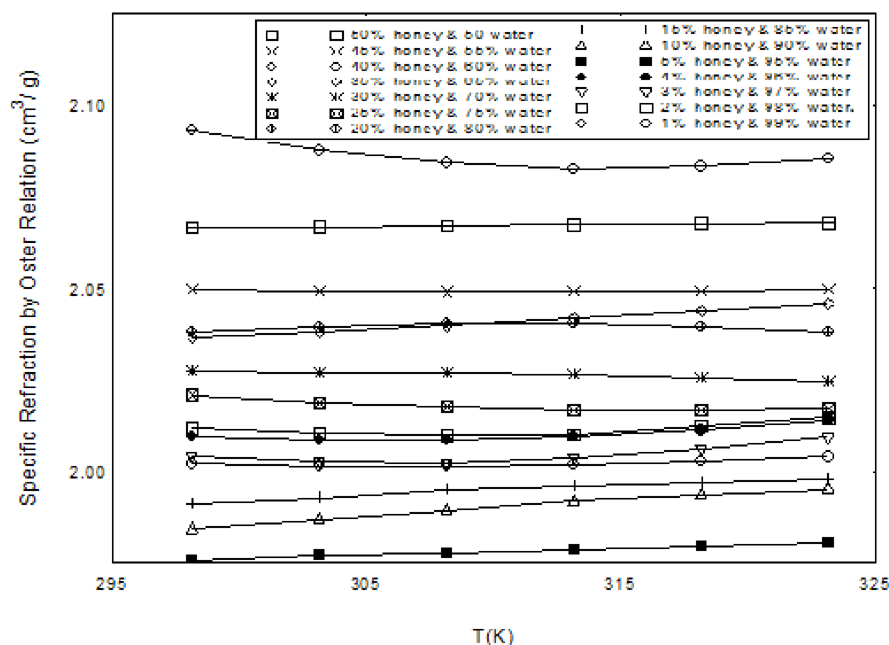


Figure (3.4.13): Specific refraction R_{OS}measured versus temperature for different concentrations of aqueous honey solutions.

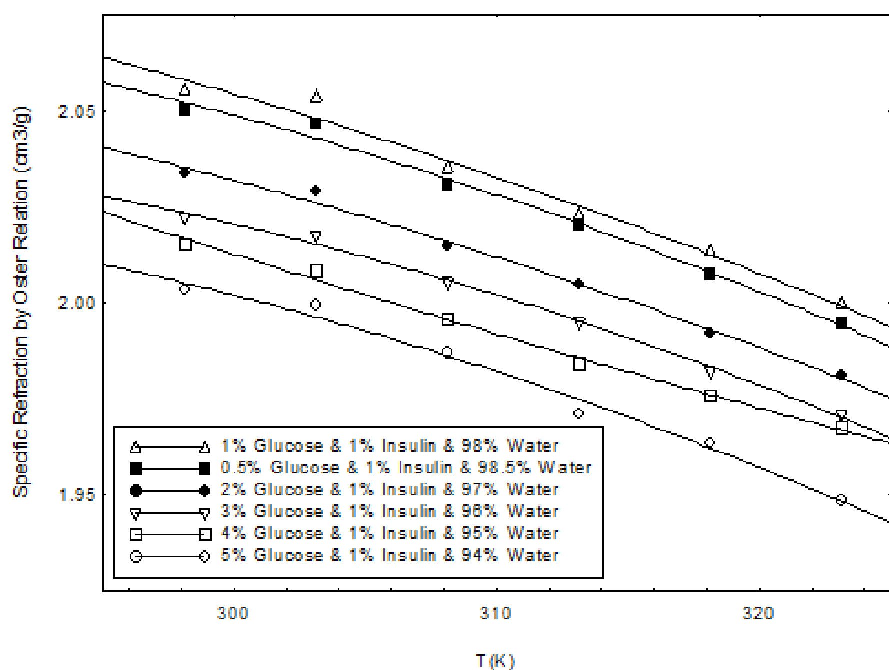


Figure (3.4.14): Specific refraction R_{OS}measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

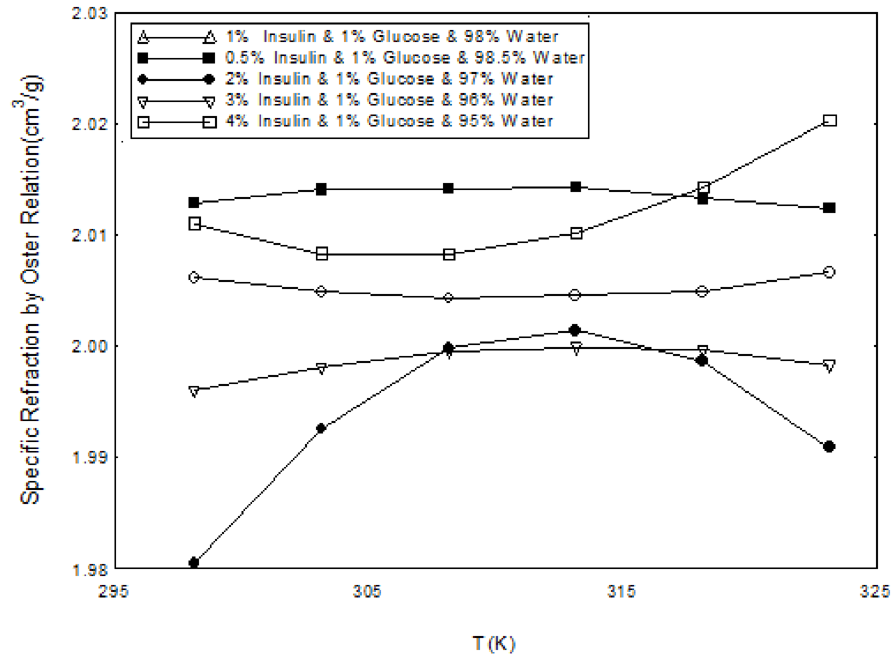


Figure (3.4.15): Specific refraction R_{OS}measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

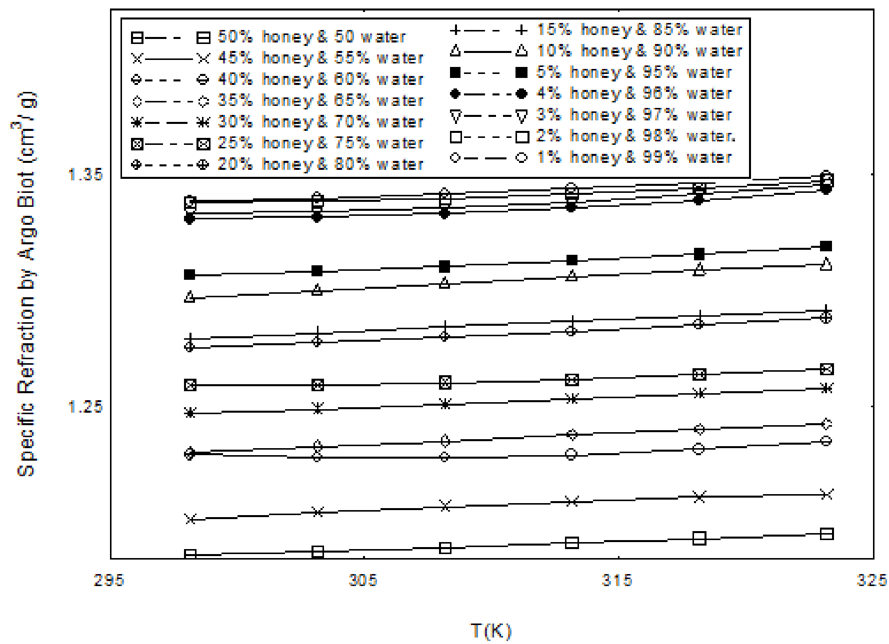


Figure (3.4.16): Specific refraction R_{AB}measured versus temperature for different concentrations of aqueous honey solutions.

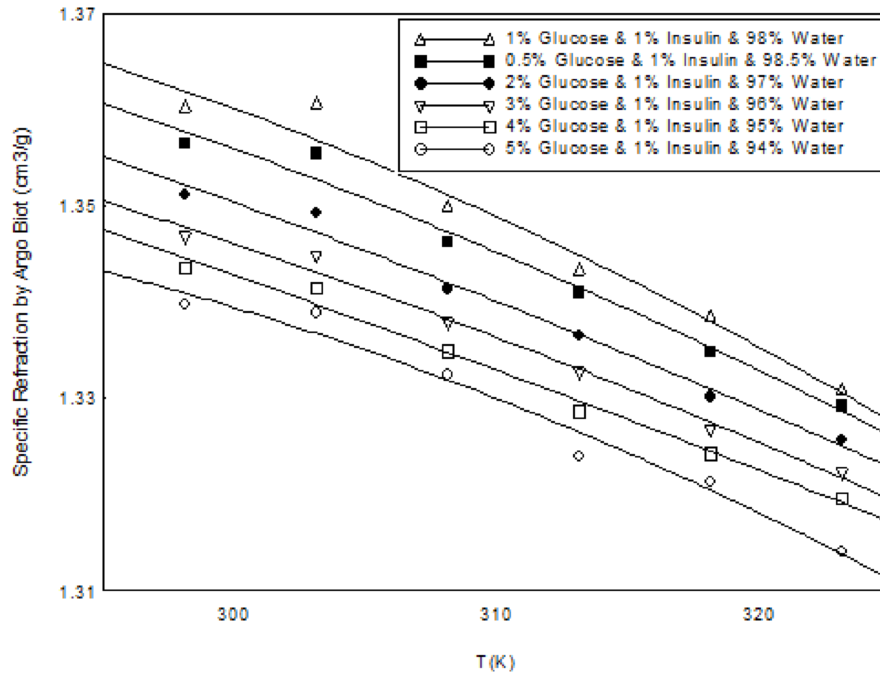


Figure (3.4.17): Specific refraction R_{AB}measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

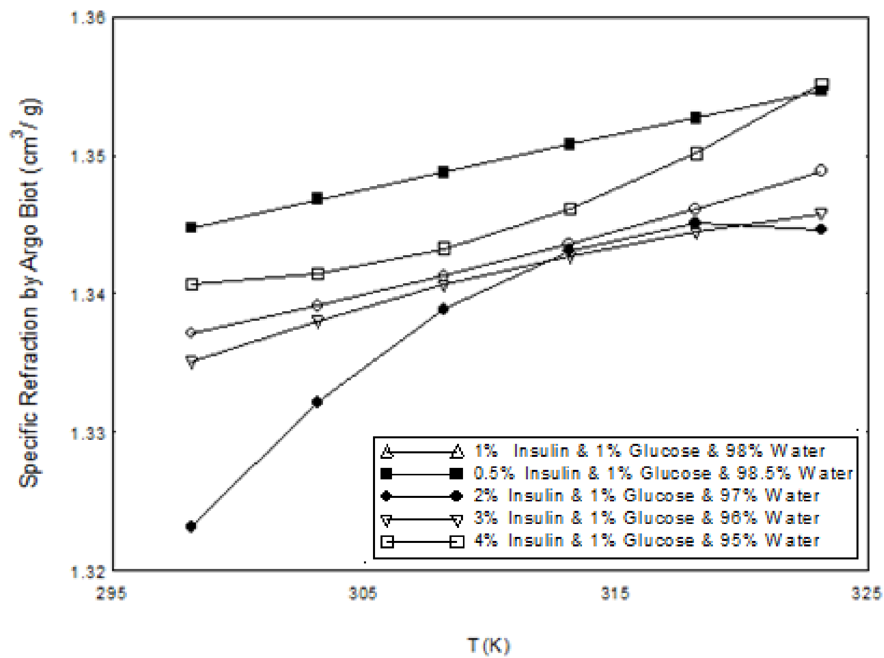


Figure (3.4.18): Specific refraction R_{AB}measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

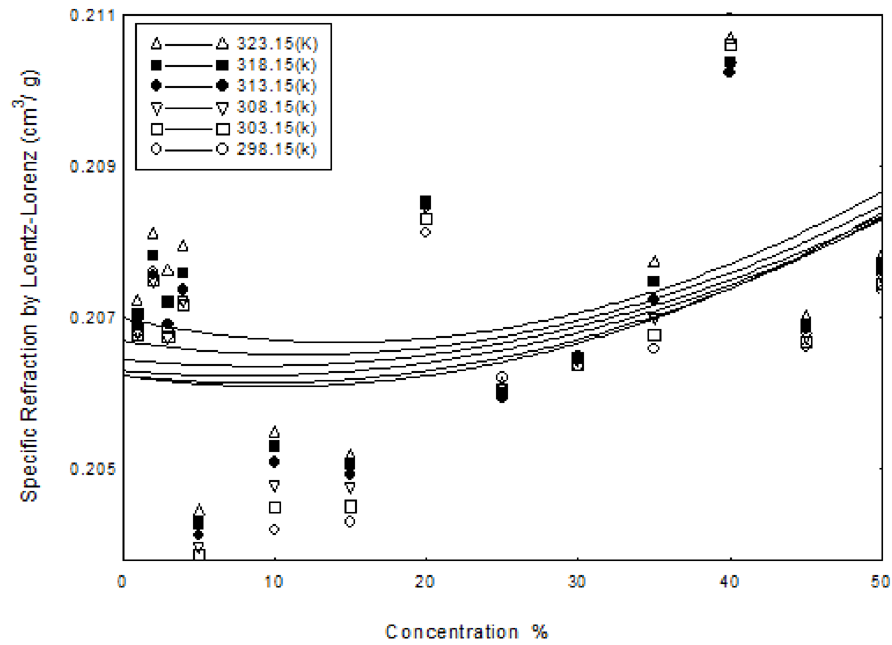


Figure (3.4.19): Specific refraction R_{LL}measured versus concentration for different temperatures of aqueous honey solutions.

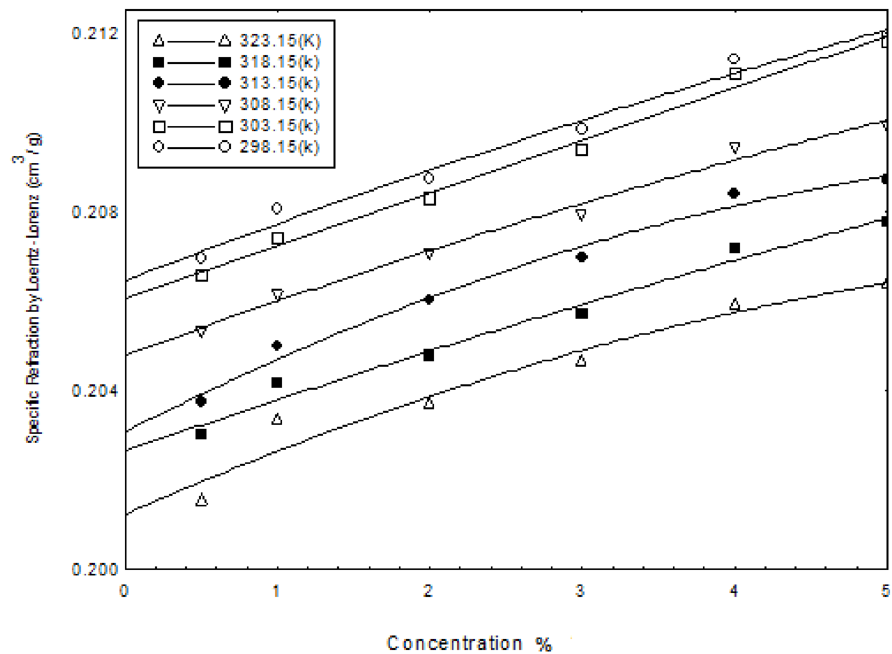


Figure (3.4.20): Specific refraction R_{LL}measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

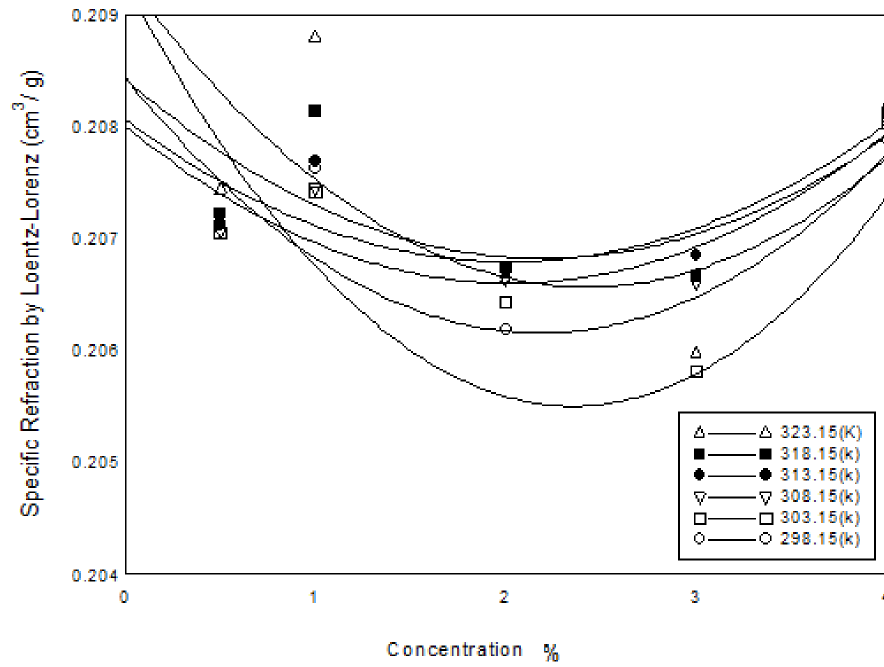


Figure (3.4.21): Specific refraction R_{LL}measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

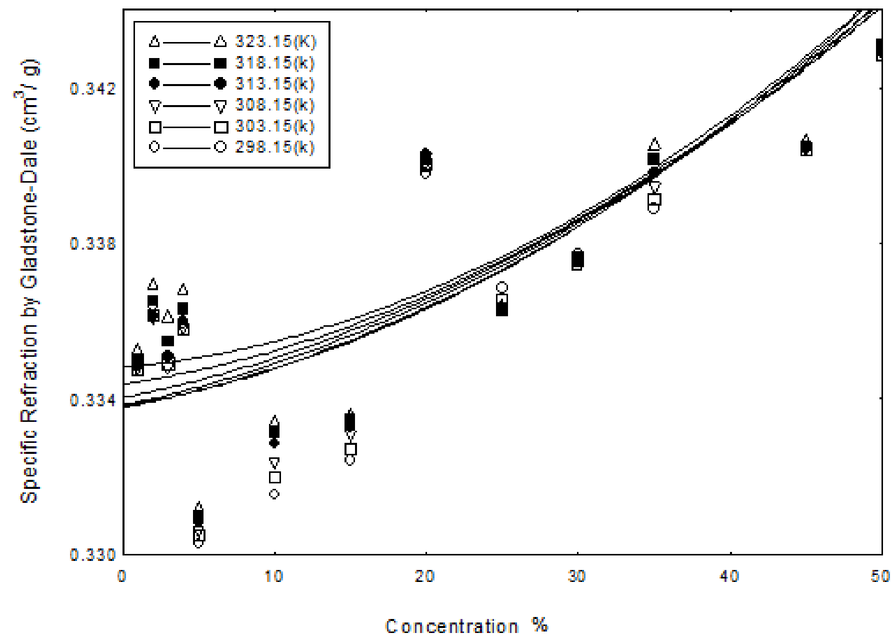


Figure (3.4.22): Specific refraction R_{GD}measured versus concentration for different temperatures of aqueous honey solutions

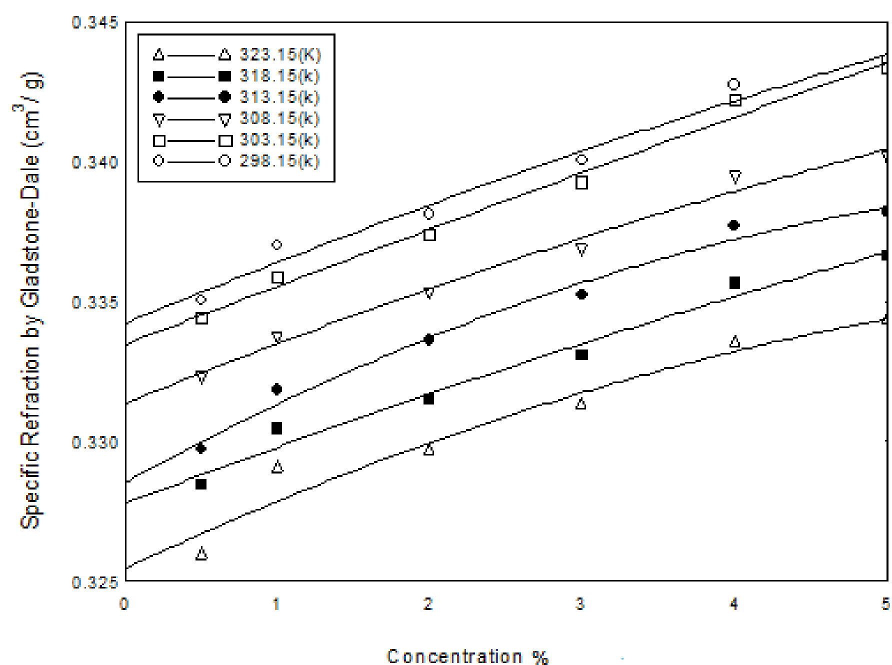


Figure (3.4.23): Specific refraction R_{GD}measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

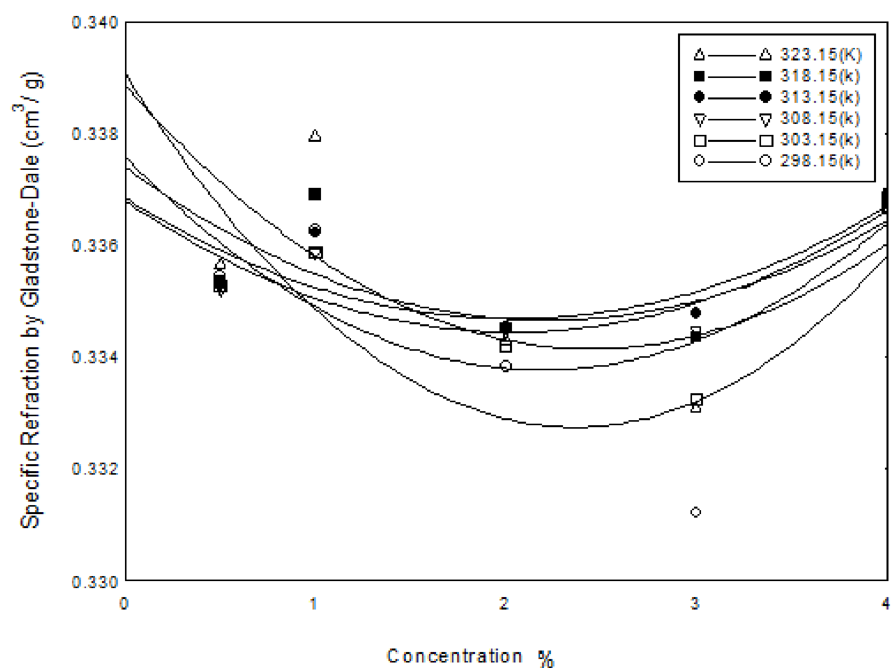


Figure (3.4.24): Specific refraction R_{GD}measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

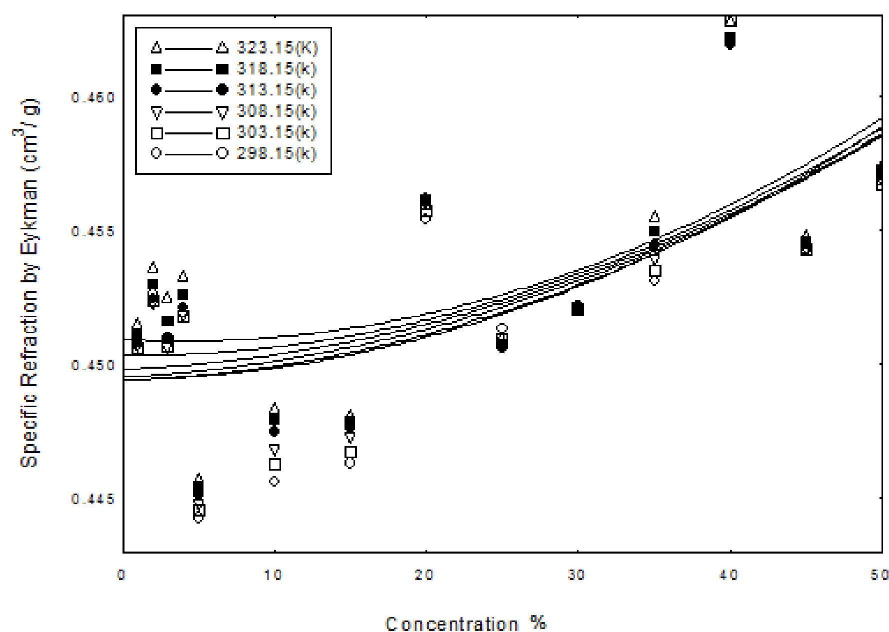


Figure (3.4.25): Specific refraction R_{EY}measured versus concentration for different temperatures of aqueous honey solutions

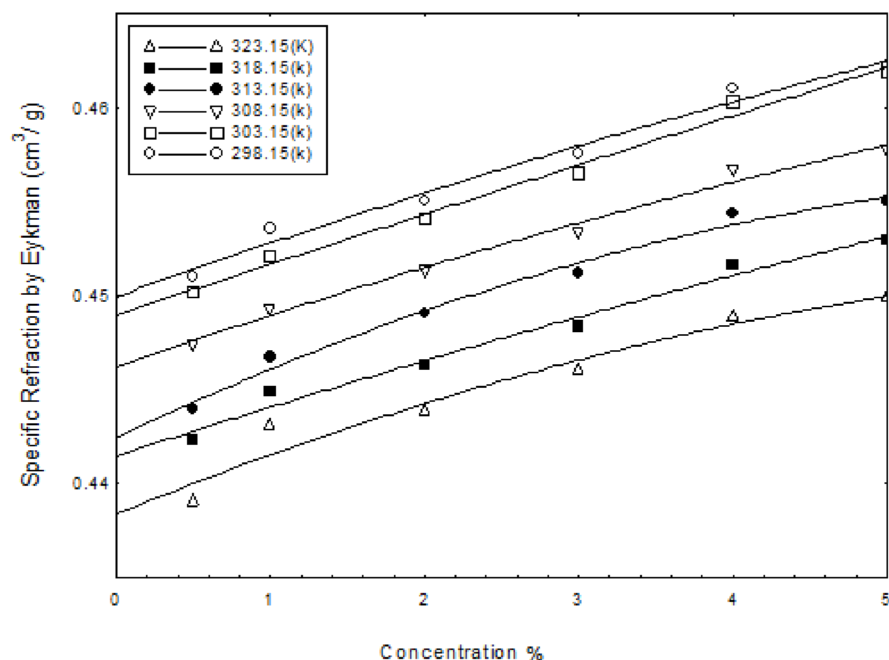


Figure (3.4.26): Specific refraction R_{EY}measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

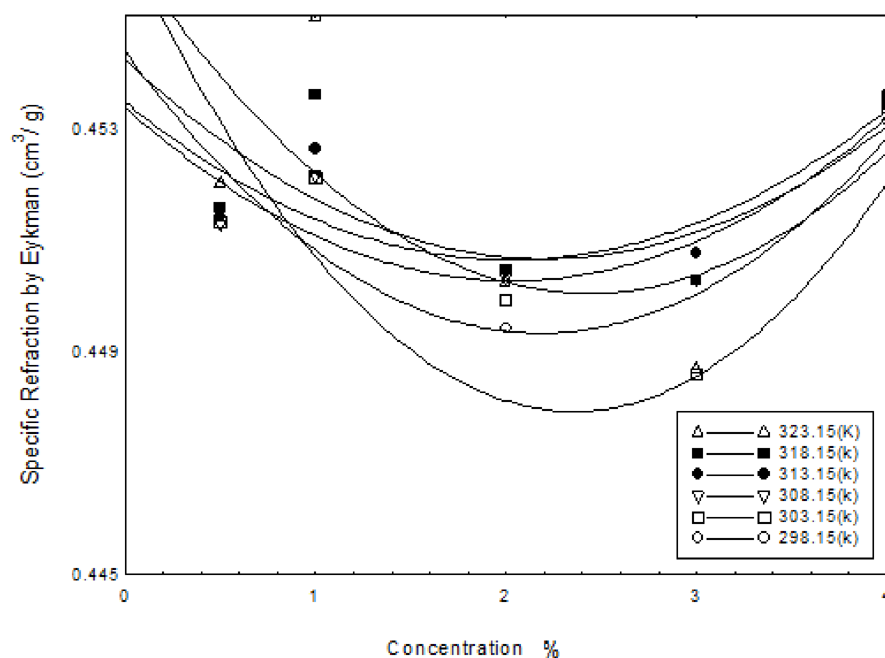


Figure (3.4.27): Specific refraction R_{EY}measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

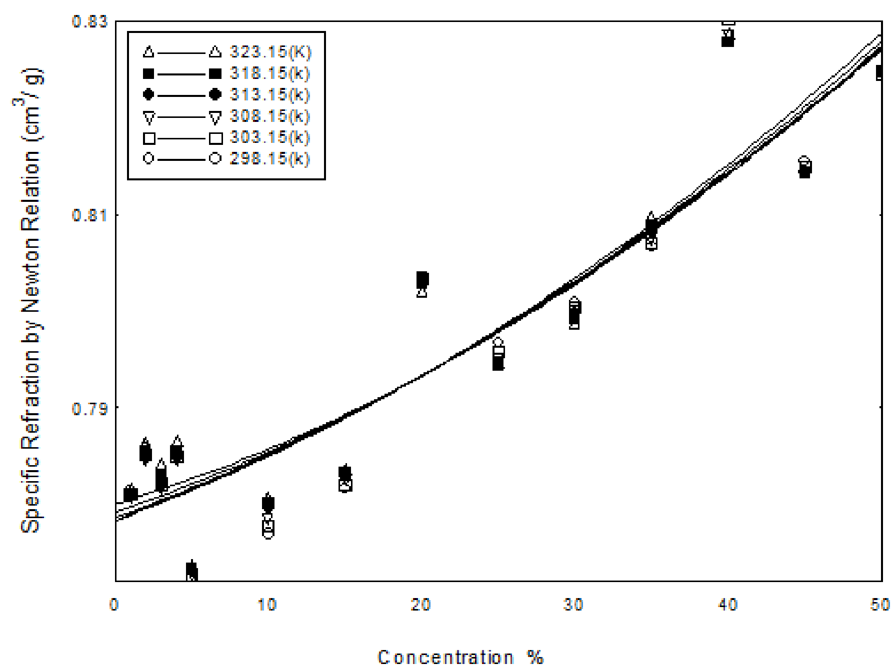


Figure (3.4.28): Specific refraction $R_N$measured versus concentration for different temperatures of aqueous honey solutions

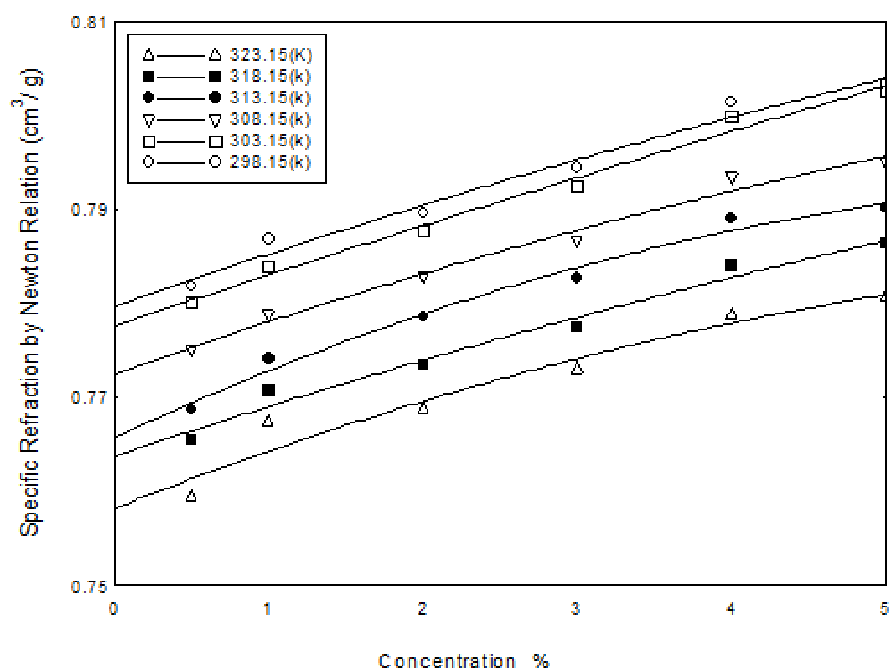


Figure (3.4.29): Specific refraction $R_N$measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

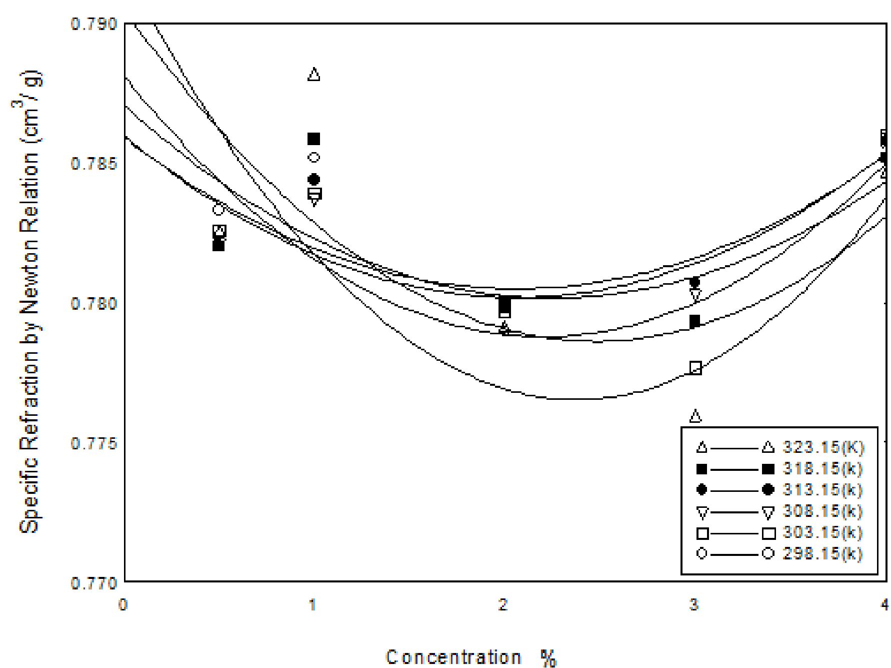


Figure (3.4.30): Specific refraction $R_N$measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

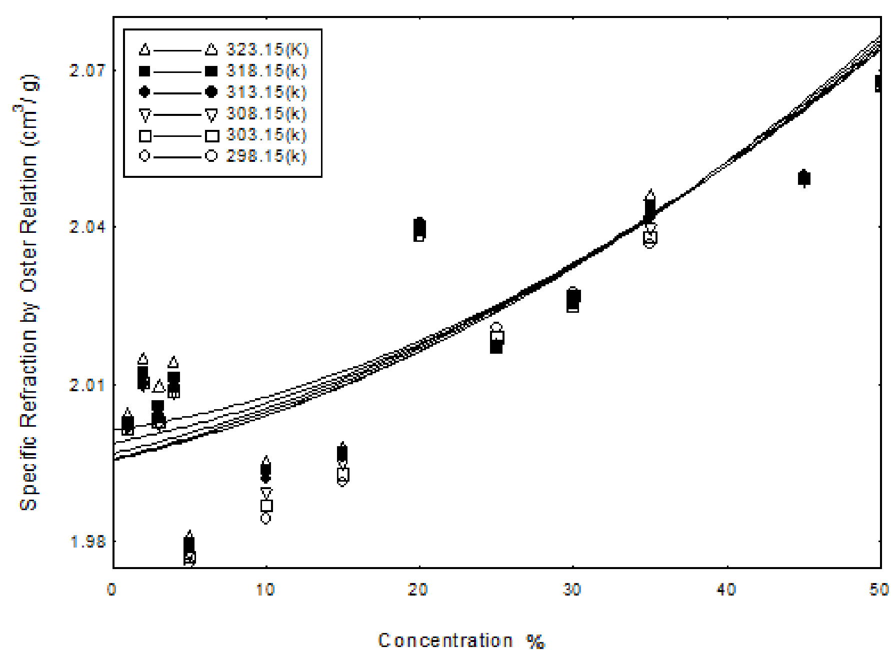


Figure (3.4.31): Specific refraction R_{OS}measured versus concentration for different temperatures of aqueous honey solutions

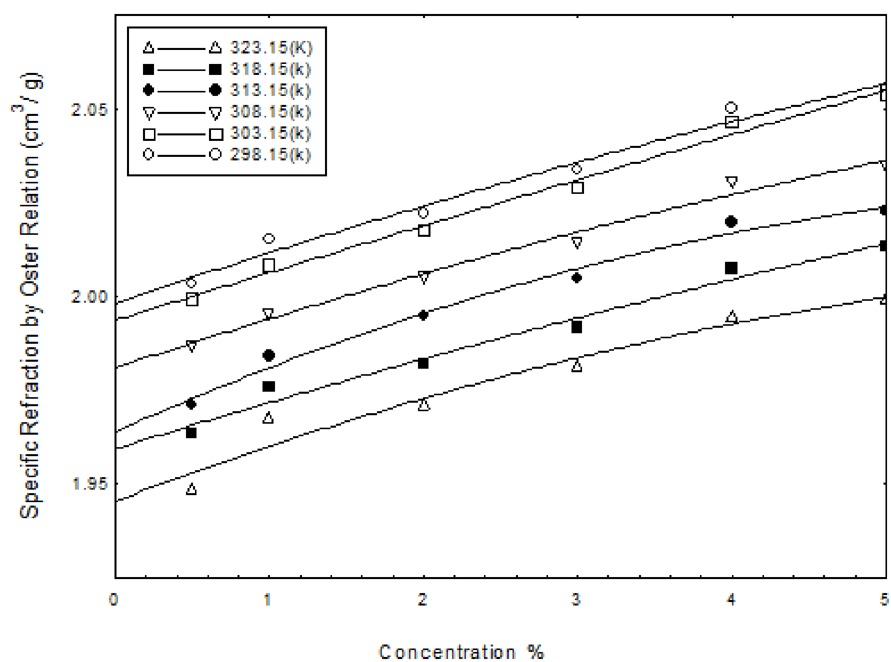


Figure (3.4.32): Specific refraction R_{OS}measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

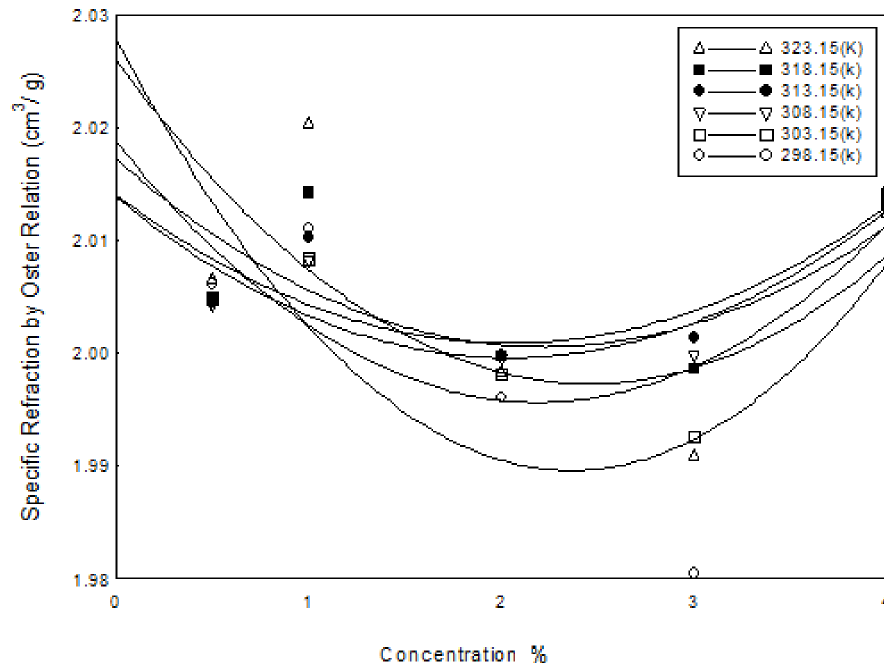


Figure (3.4.33): Specific refraction R_{OS}measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

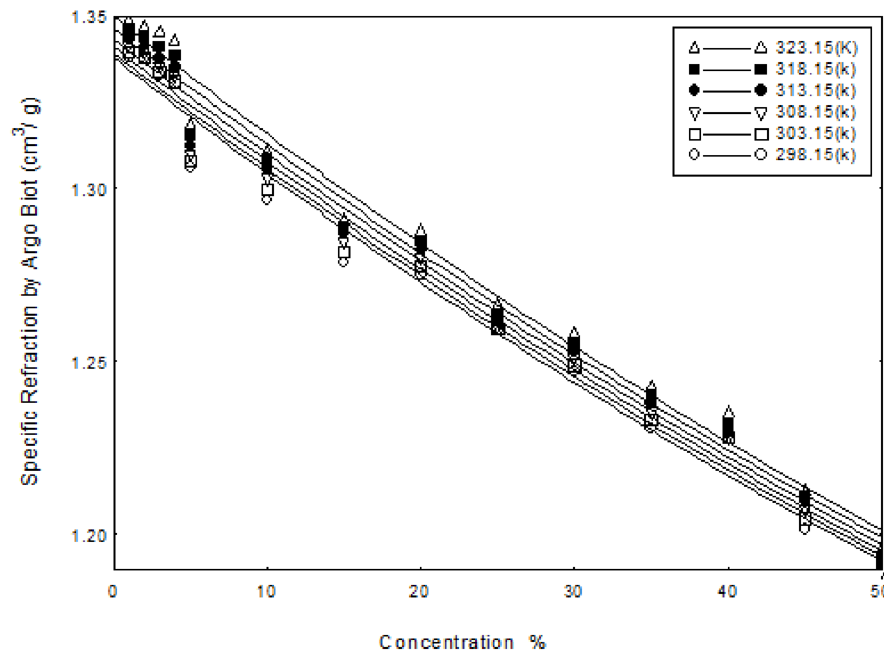


Figure (3.4.34): Specific refraction R_{AB}measured versus concentration for different temperatures of aqueous honey solutions

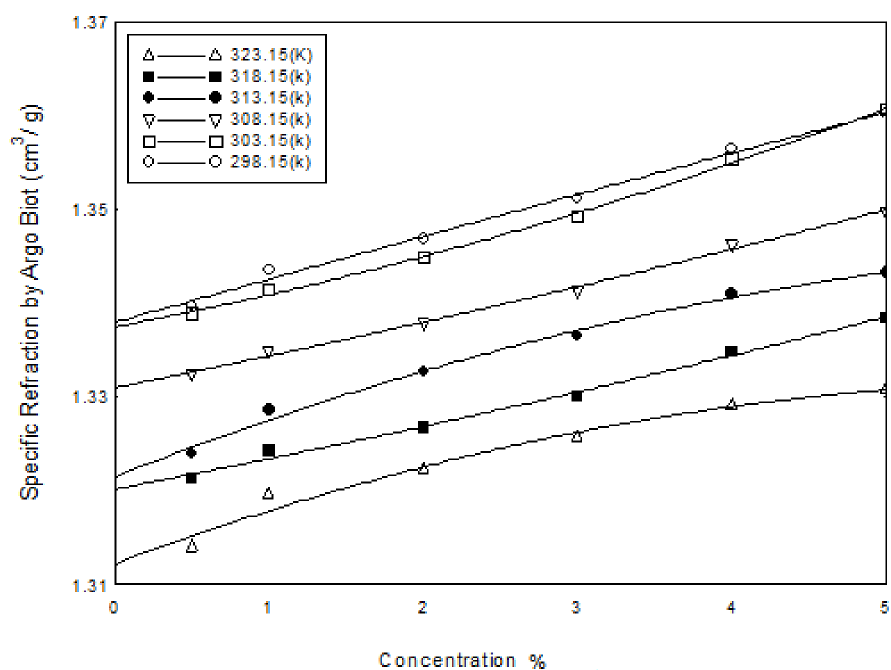


Figure (3.4.35): Specific refraction R_{AB}measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

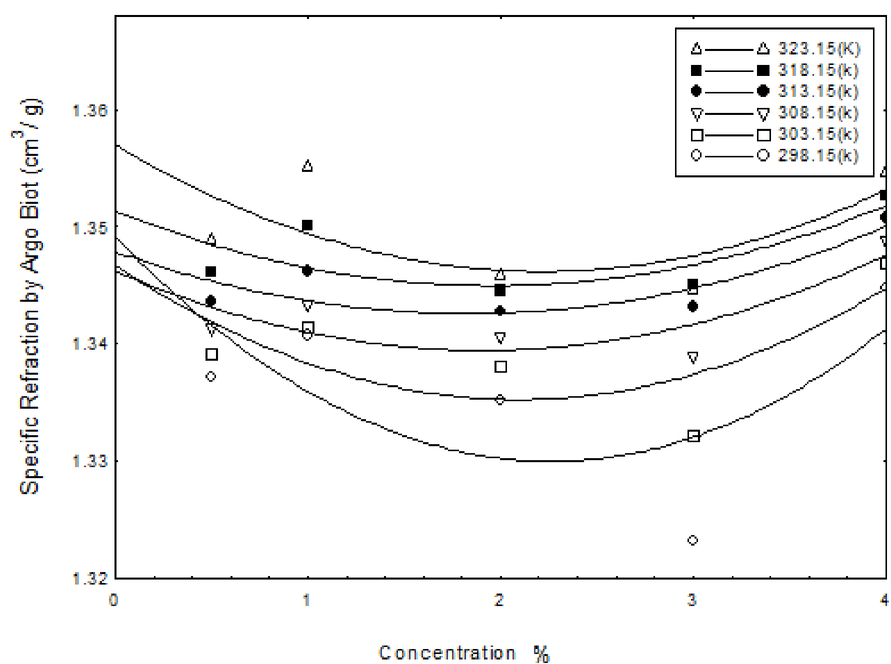


Figure (3.4.36): Specific refraction R_{AB}measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

It's clearly seen from figures (3.4.1-6) that the specific of refraction for all aqueous honey samples in all mixing rule models is approximately temperature independent. But, from figures (3.4.19-24) we can see that the specific of refraction of all aqueous honey solutions in all mixing rule models increases with increasing concentration except Argo Biot model. Figures (3.4.7-12) and (3.4.25-30) show that the specific of refraction of aqueous glucose solutions mixed with one gram of insulin in all mixing rule models increases with increasing glucose concentration and decreases with increasing temperature. The specific of refraction (Figures (3.4.13-18)) of most samples of aqueous insulin solutions mixed with one gram of glucose in all mixing rule models and is independent on temperature exept Argo Biot mixing rule model. The effect of temperature on the specific of refraction R which is calculated byLorentz Lorenz equation, Gladstone Dale relation, Eykmanrelation, Newton equation, Oster relation and AragoBiotequation could be accurately fitted by polynomial equation:

$$R = A_R + B_R T + C_R T^2 \cdots\cdots\cdots (3.4.7)$$

The fitting constants A_R, B_R, and C_R are given in tables (3.4.1-18) for all concentrations of aqueous honey and aqueous glucose insulin solutions. While, The effect of concentration on the specific of refraction R which calculated byLorentz Lorenz equation, Gladstone Dale relation, Eykmanrelation, Newton equation, Osterrelation and AragoBiotequation could be accurately fitted by polynomial equation:

$$R = A_R + B_R C + C_R C^2 \cdots\cdots\cdots (3.4.8)$$

The fitting constants A_R, B_R, and C_R are given in tables (3.4.19-36) for alltemperatures of aqueous honey and aqueous glucose insulin solutions.

Table (3.4.1): The fitting constants of temperature polynomial model of specific refraction R_{LL} for all concentrations of aqueous honey solutions.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
1%	2.E-06	-1.E-03	0.4838	0.9972
2%	4.E-06	-2.E-03	0.6722	0.9931
3%	4.E-06	-3.E-03	0.7322	0.9987
4%	3.E-06	-2.E-03	0.6108	0.9998
5%	6.E-08	-4.E-06	0.3258	0.9968

Table (3.4.2): The fitting constants of temperature polynomial model of specific refraction R_{LL} for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
0.5%	-2.50E-06	1.33E-03	0.0330	0.987
1%	5.80E-07	-5.59E-04	0.3230	0.993
2%	-2.36E-06	1.25E-03	0.0445	0.995
3%	-1.67E-06	8.18E-04	0.1140	0.993
4%	-2.15E-06	1.11E-03	0.0728	0.989
5%	-1.79E-06	8.74E-04	0.1100	0.979

Table (3.4.3): The fitting constants of temperature polynomial model of specific refraction R_{LL} for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
0.5%	1.33E-05	-8.25E-03	3.280	0.979
1%	4.30E-05	-2.63E-02	6.040	0.999
2%	-1.69E-05	1.06E-02	0.338	0.997
3%	-9.93E-05	6.21E-02	-7.710	1.000
4%	-1.05E-05	6.48E-03	1.010	0.956

Table (3.4.4): The fitting constants of temperature polynomial model of specific refraction R_{GD} for all concentrations of aqueous honey solutions.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
1%	1.E-06	-6.E-04	0.2969	0.9988
2%	2.E-06	-1.3E-03	0.4116	0.9958
3%	3.E-06	-1.6E-03	0.4522	0.9992
4%	2.E-06	-1.2E-03	0.3860	0.9998
5%	2.E-07	-8.E-05	0.2123	0.9985

Table (3.4.5): The fitting constants of temperature polynomial model of specific refraction R_{GD} for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_R (cm3/g . k2)	B_R (cm3/g . k)	A_R (cm3/g)	R^2
0.5%	-4.19E-06	2.22E-03	0.0444	0.988
1%	1.17E-06	1.06E-03	0.5480	0.994
2%	-4.14E-06	2.22E-03	0.0442	0.995
3%	-2.91E-06	1.44E-03	0.1690	0.993
4%	-3.70E-06	1.91E-03	0.1010	0.99
5%	-2.88E-06	1.40E-03	0.1830	0.98

Table (3.4.6): The fitting constants of temperature polynomial model of specific refraction R_{GD} for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
0.5%	1.24E-06	-7.57E-04	0.323	0.993
1%	4.26E-06	-2.60E-03	0.604	1.000
2%	-1.67E-06	1.06E-03	0.040	0.999
3%	-9.80E-06	6.14E-03	0.756	1.000
4%	-9.27E-07	5.83E-04	0.116	0.976

Table (3.4.7): The fitting constants of temperature polynomial model of specific refraction R_{EY} for all concentrations of aqueous honey solutions.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
1%	2.E-06	-1.E-03	0.6487	0.9982
2%	5.E-06	-2.9E-03	0.9008	0.9946
3%	6.E-06	-3.5E-03	0.9857	0.999
4%	4.E-06	-3.E-03	0.8324	0.9998
5%	2.E-07	-1.E-04	0.4514	0.9979

Table (3.4.8): The fitting constants of temperature polynomial model of specific refraction R_{EY} for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
0.5%	-5.54E-06	2.94E-03	0.0664	0.987
1%	1.41E-06	-1.31E-03	0.7200	0.993
2%	-5.34E-06	2.85E-03	0.0797	0.995
3%	-3.77E-06	1.86E-03	0.2390	0.993
4%	-4.83E-06	2.49E-03	0.1480	0.99
5%	-3.89E-06	1.90E-03	0.2430	0.979

Table (3.4.9): The fitting constants of temperature polynomial model of specific refraction R_{EY} for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
0.5%	2.80E-06	-1.72E-03	0.716	0.989
1%	9.42E-06	-5.76E-03	1.330	1.000
2%	-3.70E-06	2.33E-03	0.083	0.998
3%	2.17E-05	1.36E-02	1.680	1.000
4%	-2.14E-06	1.34E-03	0.245	0.960

Table (3.4.10): The fitting constants of temperature polynomial model of specific refraction $R_N$for all concentrations of aqueous honey solutions.

Concentration %	A (cm^3/g)	B (cm^3/g)	C (cm^3/g)	R^2
1%	4.E-06	-2.3E-03	1.1406	0.991
2%	8.E-06	-5.2E-03	1.5879	0.9867
3%	1.E-05	-6.00E-03	1.7094	0.9969
4%	6.E-06	-3.80E-03	1.3742	0.9994
5%	-6.E-07	4.E-04	0.6989	0.9867

Table (3.4.11): The fitting constants of temperature polynomial model of specific refraction $R_N$for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
0.50%	-1.03E-05	5.44E-03	0.0707	0.989
1%	3.54E-06	-3.01E-03	1.3700	0.994
2%	-1.08E-05	5.88E-03	0.0026	0.996
3%	-7.54E-06	3.79E-03	0.3340	0.994
4%	-9.40E-06	4.90E-03	0.1770	0.991
5%	-6.70E-06	3.22E-03	0.4410	0.981

Table (3.4.12): The fitting constants of temperature polynomial model of specific refraction $R_N$for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
0.5%	2.17E-06	-1.34E-03	0.542	0.983
1%	7.11E-06	-4.35E-03	1.000	1.000
2%	-2.80E-06	1.76E-03	0.580	0.997
3%	-1.64E-05	1.03E-02	-1.270	1.000
4%	-1.69E-06	1.05E-03	0.174	0.950

Table (3.4.13): The fitting constants of temperature polynomial model of specific refraction $R_{OS}$for all concentrations of aqueous honey solutions.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
1%	1.E-05	-5.9E-03	2.8998	0.9961
2%	2.E-05	-1.3E-02	4.03	0.9918
3%	3.E-05	-1.55E-02	4.3798	0.9984
4%	2.E-05	-1.06E-02	3.6214	0.9997
5%	-6.E-08	2.E-04	1.9129	0.9959

Table (3.4.14): The fitting constants of temperature polynomial model of specific refraction R_{OS} for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
0.5%	-2.53E-05	1.34E-02	0.2470	0.988
1%	7.47E-06	-6.64E-03	3.3300	0.994
2%	-2.55E-05	1.37E-02	0.2050	0.995
3%	-1.78E-05	8.88E-03	0.9730	0.993
4%	-2.26E-05	1.77E-02	0.5710	0.99
5%	-1.72E-05	8.34E-03	1.1000	0.98

Table (3.4.15): The fitting constants of temperature polynomial model of specific refraction R_{OS} for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
0.5%	5.63E-06	-3.53E-03	1.33	0.986
1%	1.74E-05	-1.07E-02	2.42	0.999
2%	-6.86E-06	4.27E-03	0.116	0.994
3%	-4.03E-05	2.51E-02	-3.14	1
4%	-4.61E-06	2.82E-03	0.355	0.982

Table (3.4.16): The fitting constants of temperature polynomial model of specific refraction R_{AB} for all concentrations of aqueous honey solutions.

Concentration %	C_R ($cm^3/g \cdot k^2$)	B_R ($cm^3/g \cdot k$)	A_R (cm^3/g)	R^2
1%	7.E-06	-3.6E-03	1.8407	0.9999
2%	1.E-05	-8.0E-03	2.5173	0.9998
3%	2.E-05	-1.08E-02	2.9358	1
4%	2.E-05	-1.06E-02	2.9036	1
5%	7.E-06	-4.E-03	1.8636	0.9999

Table (3.4.17): The fitting constants of temperature polynomial model of specific refraction R_{AB} for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
0.50%	-1.21E-05	6.46E-03	0.494	0.975
1%	-2.59E-06	5.95E-04	1.400	0.988
2%	-5.87E-06	2.61E-03	1.090	0.99
3%	-4.78E-06	1.89E-03	1.210	0.987
4%	-7.92E-06	3.76E-03	0.942	0.982
5%	-1.17E-05	6.00E-03	0.611	0.97

Table (3.4.18): The fitting constants of temperature polynomial model of specific refraction R_{AB} for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_R ($cm^3/g . k^2$)	B_R ($cm^3/g . k$)	A_R (cm^3/g)	R^2
0.5%	2.29E-07	-1.61E-04	7.72E-02	1
1%	3.15E-07	-2.10E-04	8.38E-02	1
2%	-1.35E-07	6.82E-05	4.08E-02	1
3%	-8.06E-07	4.76E-04	-2.10E-02	1
4%	-2.69E-07	1.50E-04	-2.85E-02	1

Table (3.4.19): The fitting constants of concentration polynomial model of specific refraction R_{LL} for all temperatures of aqueous honey solutions.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	0.0143	-0.0029	0.262	0.1616
303.15 (k)	0.0128	-0.0023	0.2062	0.1755
308.15 (k)	0.0115	-0.0018	0.2063	0.1788
313.15 (k)	0.0117	-0.0021	0.2064	0.1749
318.15 (k)	0.0134	-0.0031	0.2067	0.1628
323.15 (k)	0.0156	-0.0045	0.207	0.1461

Table (3.4.20): The fitting constants of concentration polynomial model of specific refraction R_{LL} for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	0.0292	0.0066	0.3338	0.5992
303.15 (k)	0.0267	0.0075	0.3338	0.6313
308.15 (k)	0.0244	0.0083	0.3338	0.6486
313.15 (k)	0.0247	0.0078	0.334	0.6549
318.15 (k)	0.0278	0.0058	0.3344	0.6449
323.15 (k)	0.0317	0.0035	0.3348	0.6229

Table (3.4.21): The fitting constants of concentration polynomial model of specific refraction R_{LL} for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	0.0363	0.0007	0.4494	0.4105
303.15 (k)	0.033	0.002	0.4494	0.4423
308.15 (k)	0.03	0.003	0.4495	0.4581
313.15 (k)	0.0303	0.0023	0.4498	0.4611
318.15 (k)	0.0344	-0.0002	0.4503	0.4458
323.15 (k)	0.0393	-0.0031	0.4509	0.4174

Table (3.4.22): The fitting constants of concentration polynomial model of specific refraction R_{GD} for all temperatures of aqueous honey solutions.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	0.0881	0.0561	0.7786	0.8352
303.15 (k)	0.0817	0.0581	0.7784	0.8518
308.15 (k)	0.0757	0.0599	0.7783	0.8612
313.15 (k)	0.0767	0.0583	0.7786	0.8663
318.15 (k)	0.0851	0.053	0.7793	0.864
323.15 (k)	0.0953	0.047	0.7801	0.8568

Table (3.4.23): The fitting constants of concentration polynomial model of specific refraction R_{GD} for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	0.1974	0.0629	1.9958	0.697
303.15 (k)	0.1818	0.0682	1.9955	0.7244
308.15 (k)	0.1675	0.0728	1.9957	0.7393
313.15 (k)	0.1695	0.0693	1.9968	0.7457
318.15 (k)	0.1889	0.0571	1.9988	0.7389
323.15 (k)	0.2125	0.0428	2.0012	0.7225

Table (3.4.24): The fitting constants of concentration polynomial model of specific refraction R_{GD} for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	0.1146	-0.3481	1.3380	0.9793
303.15 (k)	0.1064	-0.3437	1.3392	0.9836
308.15 (k)	0.1012	-0.3418	1.3410	0.9856
313.15 (k)	0.0997	-0.3422	1.3433	0.9864
318.15 (k)	0.1035	-0.3461	1.3463	0.9860
323.15 (k)	0.1090	-0.3514	1.3498	0.9843

Table (3.4.25): The fitting constants of concentration polynomial model of specific refraction R_{EY} for all temperatures of aqueous honey solutions.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15	-0.3630	0.1300	0.2070	0.98
303.15	-0.0259	0.1190	0.2060	0.990
308.15	-0.4090	0.1260	0.2050	0.989
313.15	-1.2000	0.1750	0.2030	0.987
318.15	-0.2730	0.1180	0.2030	0.981
323.15	-0.9390	0.1510	0.2010	0.953

Table (3.4.26): The fitting constants of concentration polynomial model of specific refraction R_{EY} for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15	-0.6548	0.2246	0.3342	0.9813
303.15	-0.1514	0.2092	0.3335	0.9891
308.15	-0.7902	0.2010	0.3314	0.9878
313.15	-2.0725	0.3000	0.3285	0.9858
318.15	-0.5406	0.2065	0.3278	0.9799
323.15	-1.5593	0.2561	0.3255	0.3506

Table (3.4.27): The fitting constants of concentration polynomial model of specific refraction R_{EY} for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15	-0.8325	0.2927	0.4499	0.9820
303.15	-0.1247	0.2700	0.4490	0.9896
308.15	-0.9714	0.2852	0.4462	0.9882
313.15	-2.7004	0.3915	0.4424	0.9861
318.15	-0.6563	0.2667	0.4414	0.9806
323.15	-2.0702	0.3357	0.4383	0.9516

Table (3.4.28): The fitting constants of concentration polynomial model of specific refraction R_N for all temperatures of aqueous honey solutions.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15	-1.7720	0.5725	0.7797	0.9795
303.15	-0.7482	0.5461	0.7777	0.9878
308.15	-2.3053	0.5777	0.7725	0.9866
313.15	-5.2828	0.7614	0.7658	0.9848
318.15	-1.6169	0.5387	0.7638	0.9783
323.15	-3.7802	0.6426	0.7830	0.9480

Table (3.4.29): The fitting constants of concentration polynomial model of specific refraction R_N for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15	-4.0580	1.3719	1.9983	0.9809
303.15	-1.1376	1.2852	1.9939	0.9888
308.15	-4.9965	1.3584	1.9809	0.9875
313.15	-12.6536	1.8300	1.9639	0.9855
318.15	-3.4383	1.2684	1.9593	0.9796
323.15	-9.4011	1.5576	1.9453	0.9500

Table (3.4.30): The fitting constants of concentration polynomial model of specific refraction R_N for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15	-0.3804	0.4660	1.3379	0.9939
303.15	2.9860	0.3163	1.3375	0.9975
308.15	1.0388	0.3273	1.3310	0.9966
313.15	-4.1970	0.6450	1.3215	0.9925
318.15	1.1381	0.3101	1.3202	0.9936
323.15	-4.8304	0.6114	1.3122	0.9756

Table (3.4.31): The fitting constants of concentration polynomial model of specific refraction R_{OS} for all temperatures of aqueous honey solutions.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	24.925	-1.411	0.224	1
303.15 (k)	14.257	-0.775	0.216	1
308.15 (k)	7.561	-0.381	0.211	1
313.15 (k)	5.802	-0.276	0.210	1
318.15 (k)	7.637	-0.389	0.211	1
323.15 (k)	13.940	-0.765	0.216	1

Table (3.4.32): The fitting constants of concentration polynomial model of specific refraction R_{OS} for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	40.130	-2.268	0.363	1
303.15 (k)	22.714	-1.230	0.350	1
308.15 (k)	11.916	-0.594	0.342	1
313.15 (k)	9.437	0.447	0.340	1
318.15 (k)	12.867	-0.659	0.340	1
323.15 (k)	23.751	-1.308	0.351	1

Table (3.4.33): The fitting constants of concentration polynomial model of specific refraction R_{OS} for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	54.183	-3.065	0.489	1
303.15 (k)	30.842	-1.674	0.471	1
308.15 (k)	16.275	-0.816	0.460	1
313.15 (k)	12.672	-0.602	0.457	1
318.15 (k)	16.958	-0.866	0.461	1
323.15 (k)	31.117	-1.710	0.472	1

Table (3.4.34): The fitting constants of concentration polynomial model of specific refraction R_{AB} for all temperatures of aqueous honey solutions.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	92.824	-5.236	0.847	1
303.15 (k)	51.667	-2.781	0.815	1
308.15 (k)	26.628	-1.308	0.796	1
313.15 (k)	22.178	-1.044	0.792	1
318.15 (k)	31.838	-1.642	0.800	1
323.15 (k)	59.686	-3.305	0.821	1

Table (3.4.35): The fitting constants of concentration polynomial model of specific refraction R_{AB} for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	239.459	-13.529	2.171	1
303.15 (k)	135.019	-7.304	2.090	1
308.15 (k)	70.550	-3.507	2.041	1
313.15 (k)	56.521	-2.674	2.031	1
318.15 (k)	78.001	-4.002	2.049	1
323.15 (k)	144.506	-7.969	2.100	1

Table (3.4.36): The fitting constants of concentration polynomial model of specific refraction R_{AB} for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_R (cm^3/g)	B_R (cm^3/g)	A_R (cm^3/g)	R^2
298.15 (k)	167.811	-9.587	1.460	1
303.15 (k)	102.847	-5.732	1.412	1
308.15 (k)	58.283	-3.090	1.379	1
313.15 (k)	36.319	-1.777	1.364	1
318.15 (k)	34.909	-1.687	1.364	1
323.15 (k)	55.808	-2.908	1.382	1

3.5. Thermal Gradient and Concentration Increment of Electrical Polarizability and Susceptibility of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

Polarizability of matter is the ability for a molecule to be polarized. Polarizabilities determine the dynamical response of a bound system to external fields, and provide insight into a molecule's internal structure.

Electric polarizability is the relative tendency of a charge distribution, like the electrons cloud of an atom or molecule, to be distorted from its normal shape by an external electric field, which is applied typically by inserting the molecules in a charged parallel-plate capacitor, but may also be caused by the presence of a nearby ions or dipole.

Refractive index at a given wave length λ and its temperature dependence of molecular materials can be calculated by using the Lorentz Lorenz classical equation (Ando, 2006):

$$f_{LL} = \frac{n_\lambda^2 - 1}{n_\lambda^2 + 2} = \frac{4\pi}{3}\frac{\rho N_A}{M_w}\alpha_\lambda = \frac{4\pi}{3}\frac{\alpha_\lambda}{V_{Mol}} \cdots\cdots\cdots (3.5.1)$$

Where n is the refractive index, f_{LL} the Lorentz Lorenz model function, ρ the density, N_A the Avogadro's number, M_W the molecular weight, α_λ the linear molecular polarizability and V_{Mol} the molecular volume. Polarizability means the approximate average over all possible orientations of the molecule (Khodier, 2002). Polarizability caused by the electric field component of incident electromagnetic wave called electric polarizability. The electrical polarizability per unit volume P_λ of a substance is written as (El-Zaiat, 2007):

$$P_\lambda = \frac{3}{4\pi}\frac{n_\lambda^2 - 1}{n_\lambda^2 + 2} = \frac{3}{4\pi} f_{LL} \cdots\cdots\cdots (3.5.2)$$

Figures (3.5.1), (3.5.2) and (3.5.3) show the calculated electrical polarizability at sodium D spectral line versus temperature for all concentrations of aqueous honey and aqueous glucose insulin solutions. But figure (3.5.4), (3.5.5) and (3.5.6) show the calculated electrical polarizability at sodium D spectral line versus concentration for all temperatures of aqueous honey and aqueous glucose insulin solutions.

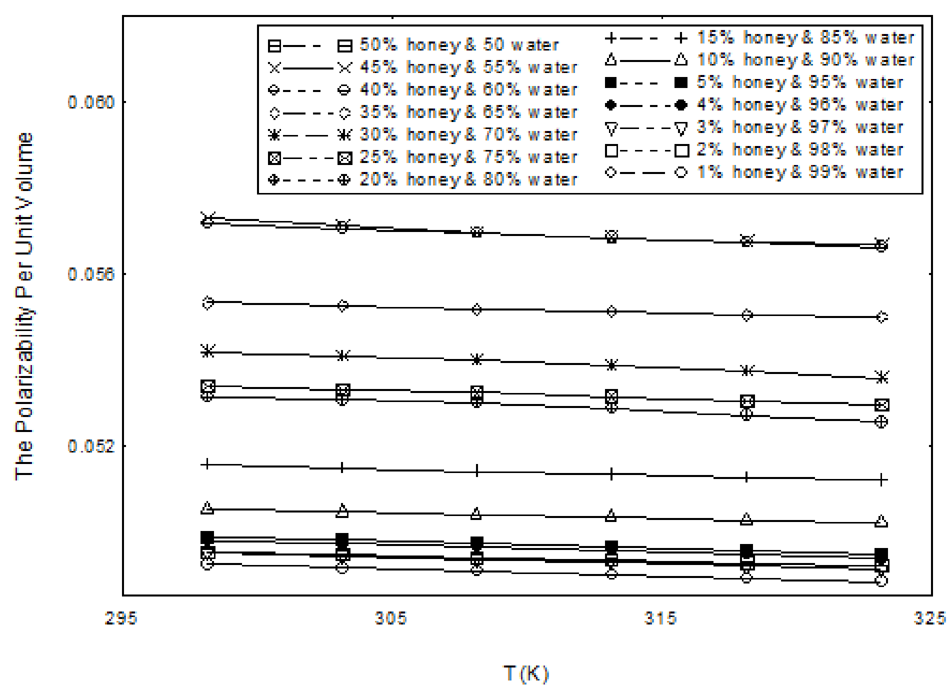


Figure (3.5.1): Electrical polarizability per unit volumemeasured versus temperature for different concentrations of aqueous honey solutions.

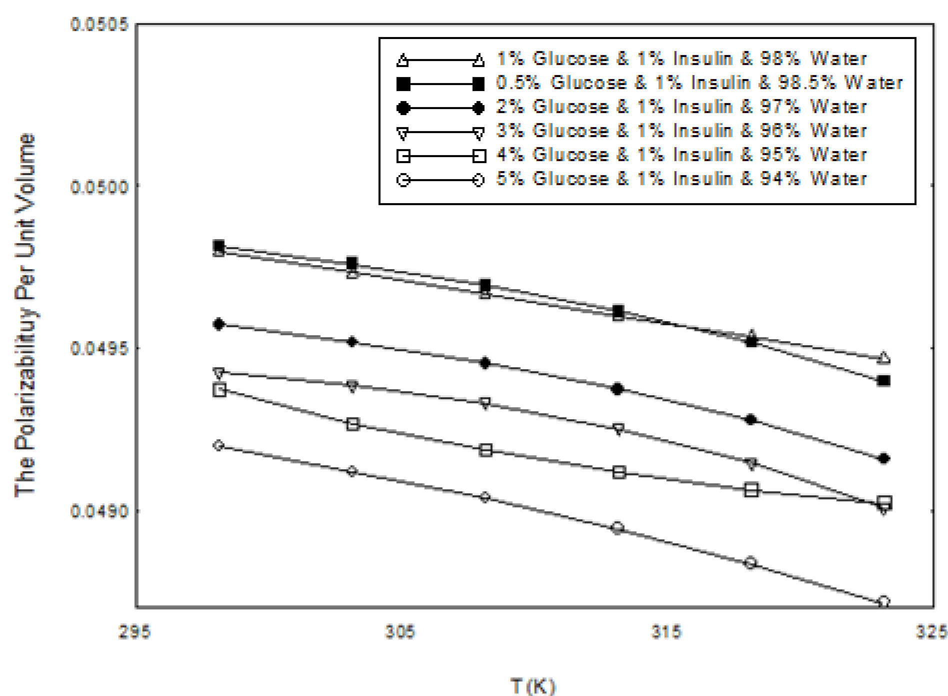


Figure (3.5.2): Electrical polarizability per unit volume measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

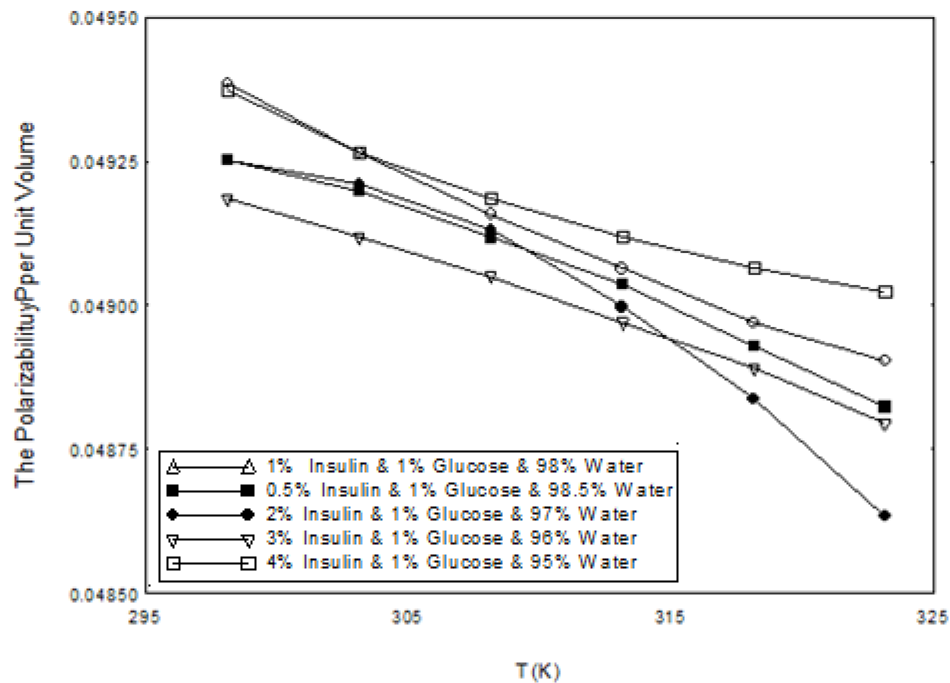


Figure (3.5.3): Electrical polarizability per unit volume measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

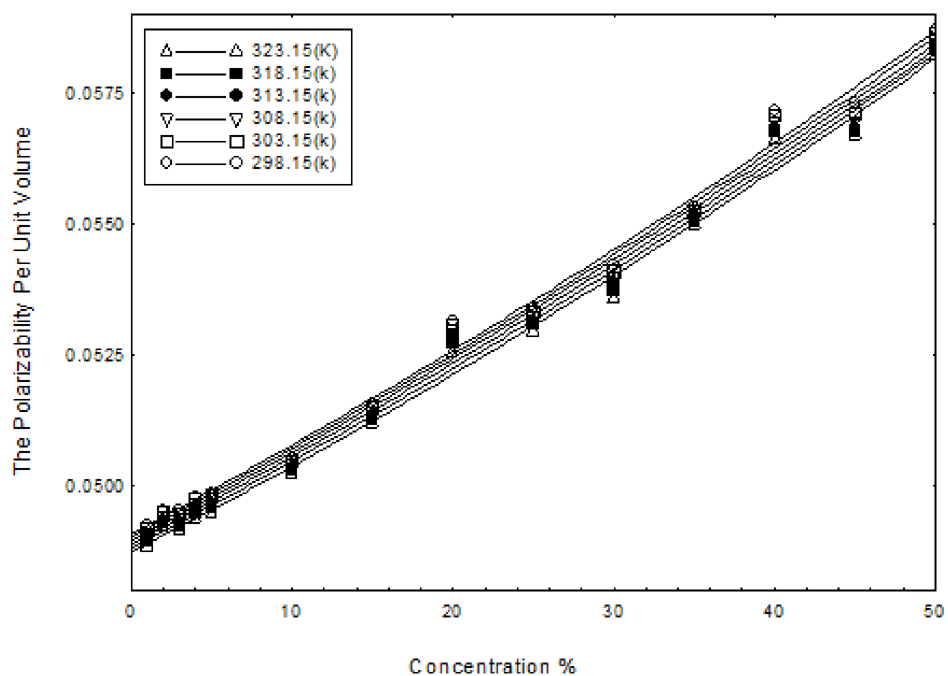


Figure (3.5.4): Electrical polarizability per unit volume measured versus concentration for different temperatures of aqueous honey solutions

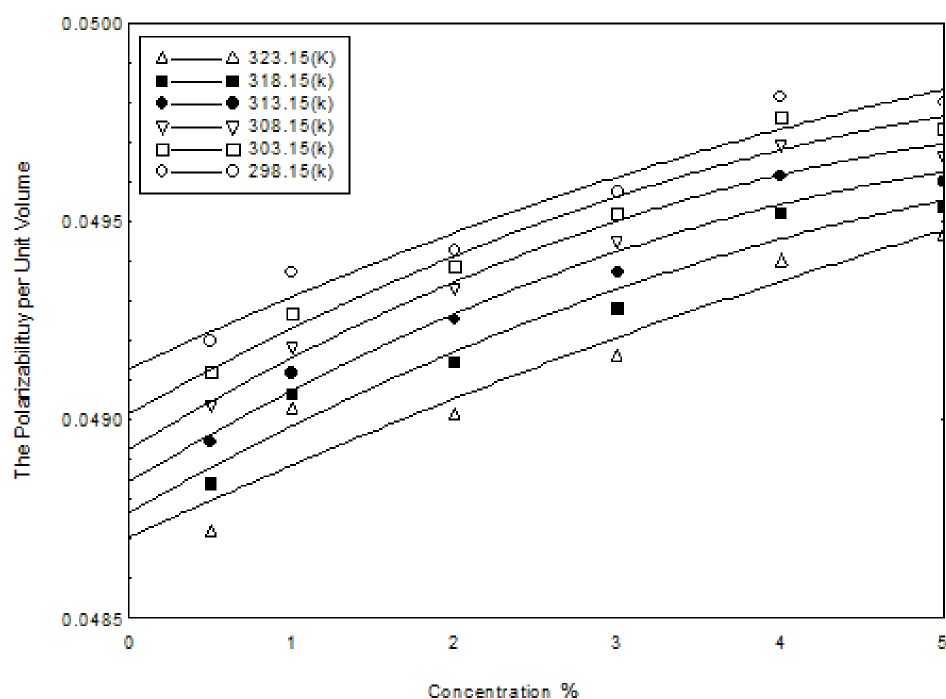


Figure (3.5.5): Electrical polarizability per unit volume measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

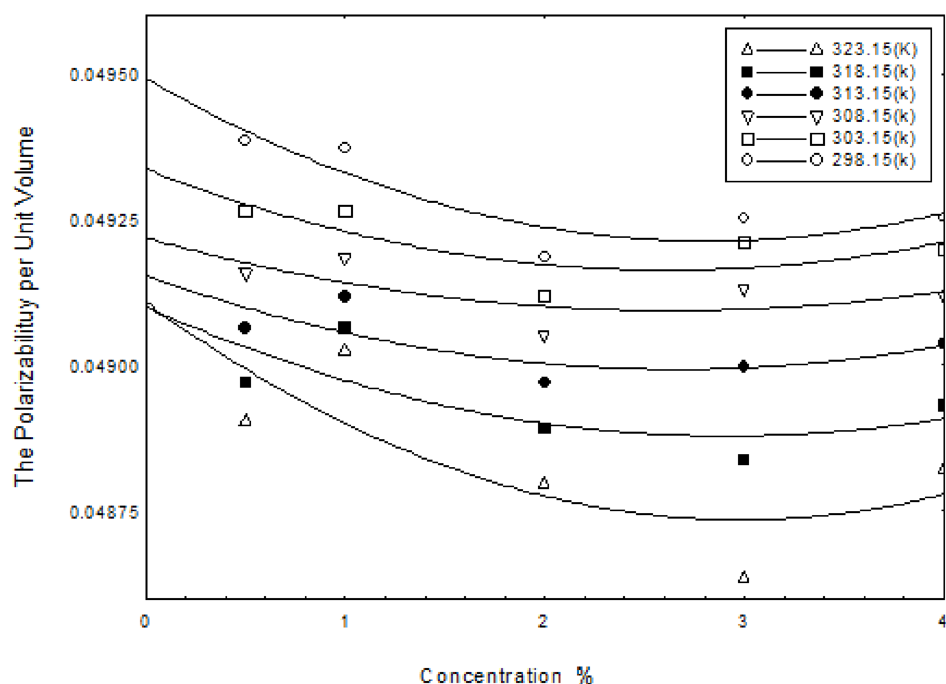


Figure (3.5.6): Electrical polarizability per unit volume measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From previous figures (3.5.1) and (3.5.4) it is noticed that the electrical polarizability per unit volume of aqeous honey samples is temperature independent, while it linearly increases with increasing honey concentration. The values of calculated electrical polarizability per unit volume of aqueous honey solutions for all temperatures and all concentrations are ranged from 0.048836 to 0.058721. Figures (3.5.2) and (3.5.5) show that the electric polarizability per unit volume increases with increasing glucose concentration and decreases with increasing temperature. The values of calculated electrical polarizability per unit volume of aqueous glucose solutions mixed with one gram of insulin for all temperatures and concentrations are ranged from 0.0487155 to 0.049799577. Figures (3.5.3) and (3.5.6) show that the electric polarizability per unit volume decreased with increasing temperature and insulin concentration. The values of calculated electrical polarizability per unit volume of aqueous insulin solutions mixed with one gram of glucose for all temperatures and concentrations are ranged from 0.048634977 to 0.049385374.The effect of temperature on the electric polarizability per unit volume could be accurately fitted by polynomial equation:

$$P_{\lambda} = A_{oP} + B_{oP}T + C_{oP}T^{2} \cdots\cdots\cdots\cdots (3.5.3)$$

The fitting constants A_{oP}, B_{oP}, and C_{oP} are given in tables (3.5.1), (3.5.2) and (3.5.3) for all concentrations of aqueous honey and aqueous glucose insulin solutions. While, the effect of concentration on the electric polarizability per unit volume could be accurately fitted by polynomial equation:

$$P_{\lambda} = A_{oP} + B_{oP}C + C_{oP}C^{2} \cdots\cdots\cdots\cdots (3.5.4)$$

The fitting constants A_{oP}, B_{oP}, and C_{oP} are given in tables (3.5.4), (3.5.5) and (3.5.6) for all temperatures of aqueous honey and aqueous glucose insulin solutions.

Table (3.5.1): The fitting constants of temperature polynomial model of electric polarizability for all concentrations of aqueous honey solutions.

Concentration %	C_{oP} (k^{-2})	B_{oP} (k^{-1})	A_{oP}	R^2
1%	-4.E-09	-1.E-05	0.0537	1
2%	3.E-08	-3.E-05	0.0566	0.9995
3%	-5.E-08	2.E-05	0.0492	0.9996
4%	3.E-07	2.E-04	0.0286	1
5%	-3.E-07	2.E-04	0.0243	0.9997

Table (3.5.2): The fitting constants of temperature polynomial model of electric polarizability for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_{oP} (k^{-2})	B_{oP} (k^{-1})	A_{oP}	R^2
0.5%	-2.21E-07	1.18E-04	3.36E-02	1
1%	3.15E-07	-2.10E-04	8.38E-02	1
2%	-4.88E-07	2.87E-04	7.29E-03	1
3%	-3.16E-07	1.80E-04	2.40E-02	1
4%	-3.16E-07	1.80E-04	2.43E-02	1
5%	-4.41E-10	-1.31E-05	5.37E-02	1

Table (3.5.3): The fitting constants of temperature polynomial model of electric polarizability for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_{oP} (k^{-2})	B_{oP} (k^{-1})	A_{oP}	R^2
0.5%	2.29E-07	-1.61E-04	7.72E-02	1
1%	3.15E-07	-2.10E-04	8.38E-02	1
2%	-1.35E-07	6.82E-05	4.08E-02	1
3%	-8.06E-07	4.76E-04	-2.10E-02	1
4%	-2.69E-07	1.50E-04	-2.85E-02	1

Table (3.5.4): The fitting constants of concentration polynomial model of electric polarizability for all temperatures of aqueous honey solutions.

T(K)	C_{oP}	B_{oP}	A_{oP}	R^2
298.15 (k)	0.0056	0.0165	0.0491	0.9927
303.15 (k)	0.0055	0.0164	0.049	0.9922
308.15 (k)	0.0053	0.0164	0.0489	0.9918
313.15 (k)	0.0054	0.0163	0.0489	0.9921
318.15 (k)	0.0058	0.016	0.0488	0.9924
323.15 (k)	0.0063	0.0158	0.0487	0.9931

Table (3.5.5): The fitting constants of concentration polynomial model of electric polarizability for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_{oP}	B_{oP}	A_{oP}	R
298.15	-0.1020	0.0190	0.0490	0.9480
303.15	-1.6300	0.0230	0.0490	0.9660
308.15	-0.1900	0.0250	0.0490	0.9700
313.15	-0.1860	0.0249	0.0488	0.9696
318.15	-0.1513	0.0233	0.4880	0.9567
323.15	-0.0671	0.0188	0.0487	0.9147

Table (3.5.6): The fitting constants of concentration polynomial model of electric polarizability for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_{oP}	B_{oP}	A_{oP}	R^2
298.15 (k)	-0.335	0.023	0.049	1
303.15 (k)	-0.536	0.036	0.049	1
308.15 (k)	-0.469	0.031	0.049	1
313.15 (k)	0.067	-0.001	0.049	1
318.15 (k)	0.737	-0.042	0.049	1
323.15 (k)	1.744	-0.103	0.050	1

The derivative to temperature of the temperature polynomial equation gives the thermal gradient of electric polarizability per unit volume:

$$\frac{dP_\lambda}{dT} = A_P + B_P T + C_P T^2 \cdots\cdots\cdots (3.5.5)$$

Where $A_P = B_{oP}$ and $B_P = 2C_{oP}$. The constants of the polynomial equation of temperature gradient of electric polarizability per unit volume for all concentrations of aqueous honey and aqueous glucose insulin solutions were given respectively in tables (3.5.7), (3.5.8) and (3.5.9).

Table (3.5.7): The fitting constants of temperature polynomial model of temperature gradient of electric polarizability for all concentrations of aqueous honey solutions.

Concentration %	A_P (k^{-1})	B_P (k^{-2})	(	R^2
1%	-1.E-05	-8.0E-09	0	1
2%	-3.E-05	6.0E-08	0	1
3%	2.E-05	-1.0E-07	0	1
4%	2.E-04	6.0E-07	0	1
5%	2.E-04	-6.0E-07	0	1

Table (3.5.8): The fitting constants of temperature polynomial model of temperature gradient of electric polarizability for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_P (k^{-1})	B_P (k^{-2})	(	R^2
0.5%	1.18E-04	-4.4E-07	0	1
1%	-2.10E-04	6.3E-07	0	1
2%	2.87E-04	-9.8E-07	0	1
3%	1.80E-04	-6.3E-07	0	1
4%	1.80E-04	-6.3E-07	0	1
5%	-1.31E-05	-8.8E-10	0	1

Table (3.5.9): The fitting constants of temperature polynomial model of temperature gradient of electric polarizability for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_P (k^{-1})	B_P (k^{-2})	C	R^2
0.5%	-1.61E-04	4.58E-07	0	1
1%	-2.10E-04	6.30E-07	0	1
2%	6.82E-05	-2.70E-07	0	1
3%	4.76E-04	-1.61E-06	0	1
4%	1.50E-04	-5.38E-07	0	1

The derivative to concentration of the concentration polynomial equation gives the concentration increment of electric polarizability per unit volume:

$$\frac{dP_\lambda}{dC} = A_P + B_P C + C_P C^2 \cdots\cdots\cdots (3.5.6)$$

Where $A_P = B_{oP}$ and $B_P = 2C_{oP}$. The constants of the polynomial equation of concentration increment of electric polarizability per unit volume for all temperatures of aqueous honey and aqueous glucose insulin solutions were given respectively in tables (3.5.10), (3.5.11) and (3.5.12).

Table (3.5.10): The fitting constants of concentration polynomial model of concentration increment of electric polarizability for all temperatures of aqueous honey solutions.

T(K)	A_P	B_P		R^2
298.15 (k)	0.0165	0.011	0	1
303.15 (k)	0.0164	0.011	0	1
308.15 (k)	0.0164	0.011	0	1
313.15 (k)	0.0163	0.011	0	1
318.15 (k)	0.016	0.012	0	1
323.15 (k)	0.0158	0.013	0	1

Table (3.5.11): The fitting constants of concentration polynomial model of concentration increment of electric polarizability for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_P	B_P		R^2
298.15 (k)	0.0190	-0.204	0	1
303.15 (k)	0.0230	-3.26	0	1
308.15 (k)	0.0250	-0.38	0	1
313.15 (k)	0.0249	-0.372	0	1
318.15 (k)	0.0233	-0.303	0	1
323.15 (k)	0.0188	-0.134	0	1

Table (3.5.12): The fitting constants of concentration polynomial model of concentration increment of electric polarizability for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_P	B_P		R^2
298.15 (k)	0.023	-0.67	0	1
303.15 (k)	0.036	-1.072	0	1
308.15 (k)	0.031	-0.938	0	1
313.15 (k)	-0.001	-0.134	0	1
318.15 (k)	-0.042	-1.474	0	1
323.15 (k)	-0.103	-3.488	0	1

In electromagnetism, the electric susceptibility is a dimensionless proportionality constant that indicates the degree of polarization of a dielectric material in response to an applied electric field. The greater the electric susceptibility, the greater the ability of a material to polarize in response to the field, and thereby reduces the total electric field inside the material (and store energy);ie the electric susceptibility influences the electric permittivity of the material and thus influences many other phenomena in that medium, from the capacitance of capacitors to the speed of light. The susceptibility is related to the polarizability of

individual particles in the medium by the ClausiusMossotti relation. The susceptibility is related to its relative permittivity.

Electric susceptibility $\chi_e$per unit volume can be determined using the electric polarizability per unit volume P_λ by the following relation (Sivasubramanian*et al.*, 2002):

$$\chi_e = P_\lambda / \left[1 - \frac{4\pi}{3} P_\lambda\right] \cdots\cdots\cdots (3.5.7)$$

Figures (3.5.7), (3.5.8) and (3.5.9) show the calculated electric susceptibility per unit volume versus temperature for all concentrations of aqueous honey and aqueous glucose insulin solutions. While Figures (3.5.10), (3.5.11) and (3.5.12) show the calculated electric susceptibility per unit volume versus concentration for all temperatures of aqueous honey and aqueous glucose insulin solutions.

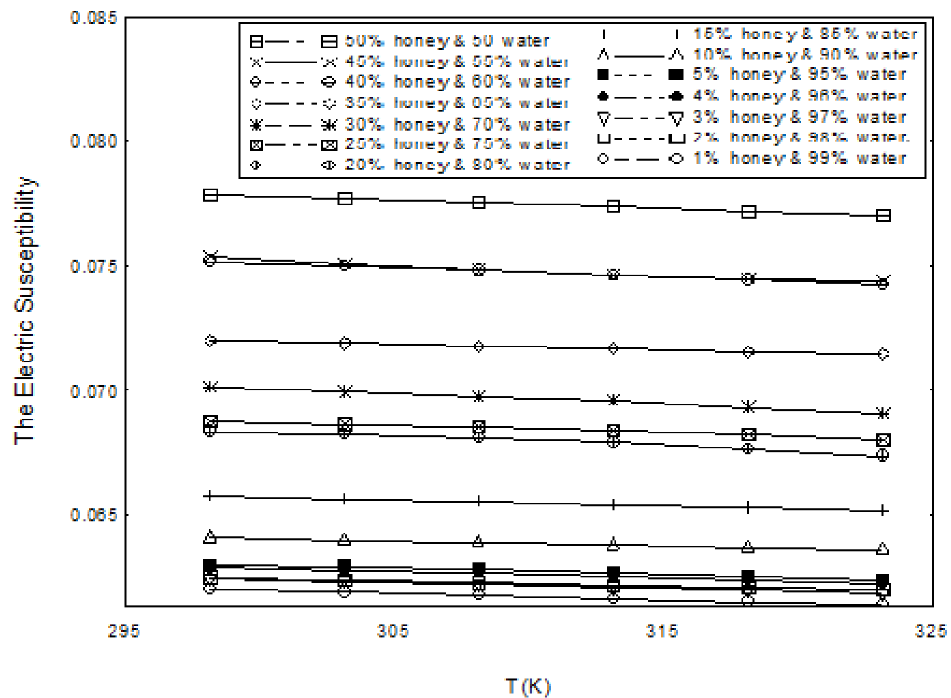


Figure (3.5.7): Electric susceptibility per unit volume measured versus temperature for different concentrations of aqueous honey solutions.

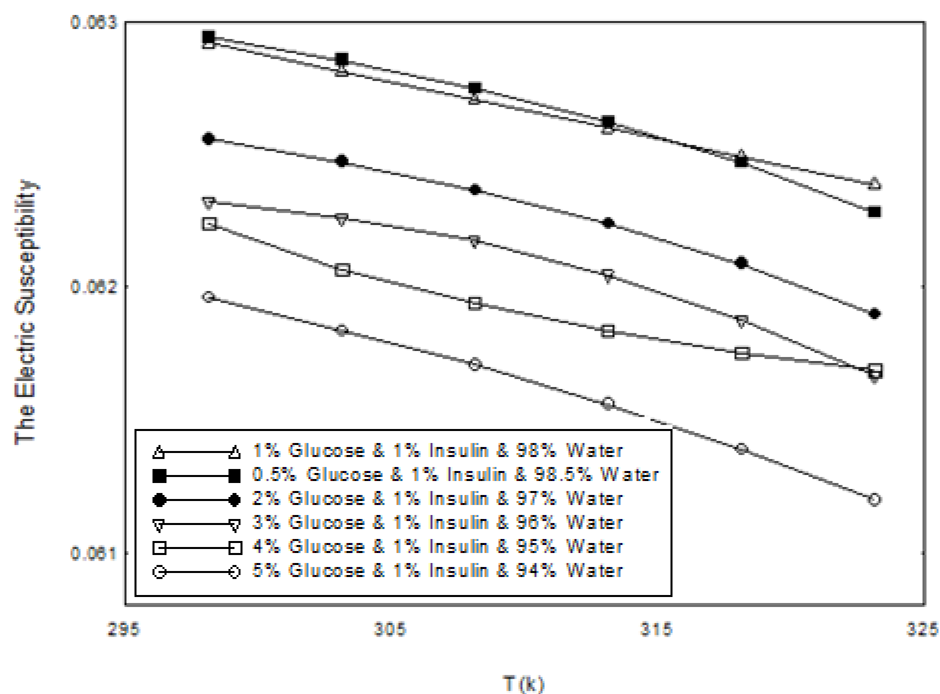


Figure (3.5.8): Electric susceptibility per unit volume measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

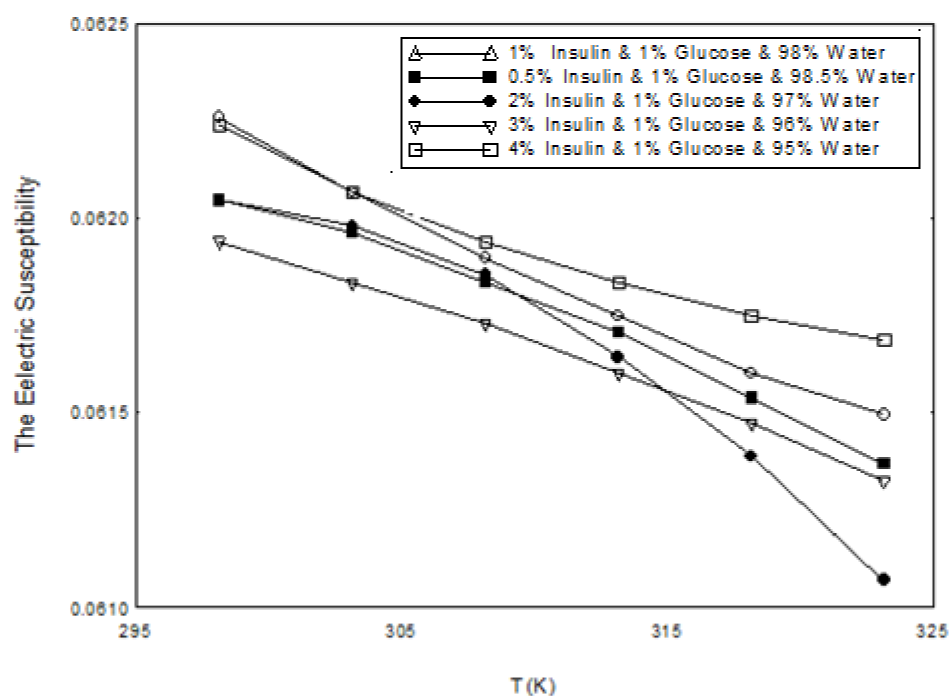


Figure (3.5.9): Electric susceptibility per unit volume measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

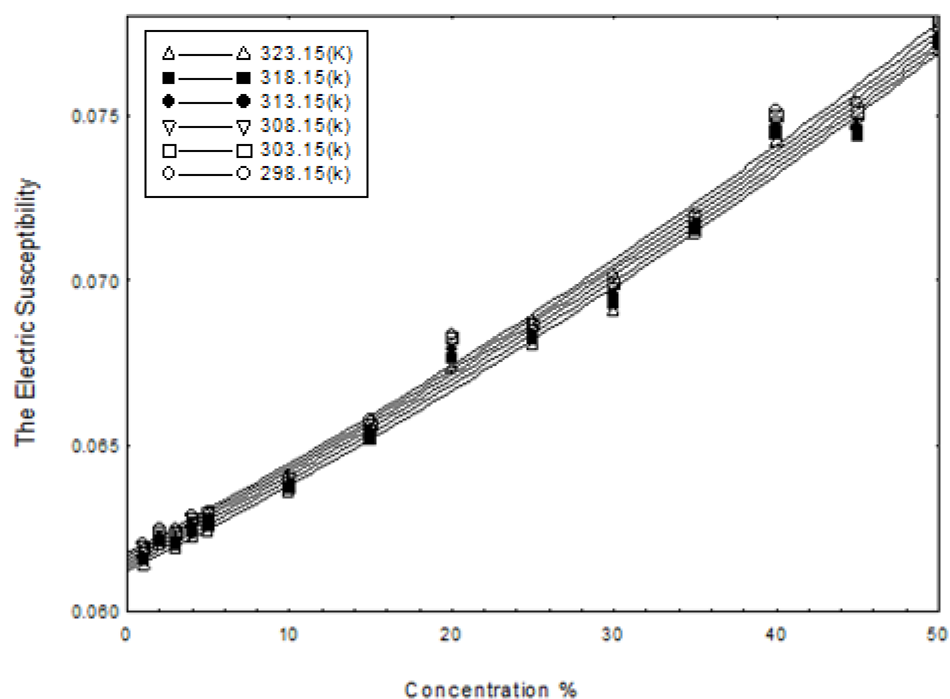


Figure (3.5.10): Electric susceptibility per unit volume measured versus concentration for different temperatures of aqueous honey solutions

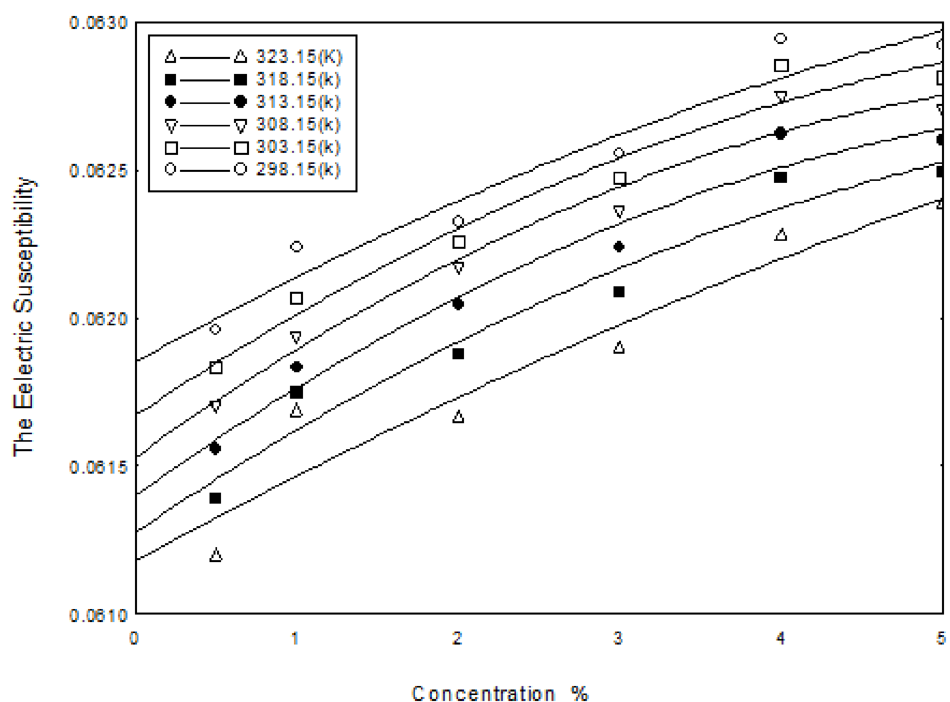


Figure (3.5.11): Electric susceptibility per unit volume measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

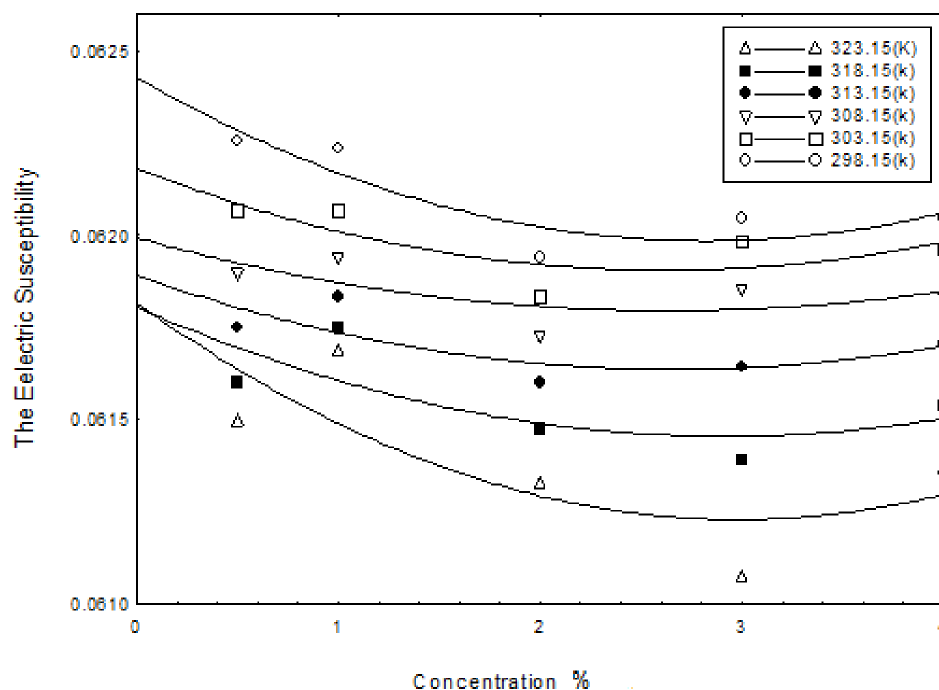


Figure (3.5.12): Electric susceptibility per unit volume measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From previous figures (3.5.7) and (3.5.10) we can notice that the electrical susceptibility per unit volume of aqueous honey samples is temperature independent, while it linearly increases with increasing honey concentration. The values of calculated electrical susceptibility per unit volume of aqueous honey solutions for all temperatures and all concentrations are ranged from 0.061388 to 0.077863. Figures (3.5.8) and (3.5.11) show that the electric susceptibility per unit volume increases with increasing glucose concentration and decreases with increasing temperature. The values of calculated electrical susceptibility per unit volume of aqueous glucose solutions mixed with one gram of insulin for all temperatures and concentrations are ranged from 0.06119697 to 0.062917516. Figures (3.5.9) and (3.5.12) show that the electric susceptibility per unit volume decreases with increasing temperature and insulin concentration. The values of calculated electrical susceptibility

per unit volume of aqueous insulin solutions mixed with one gram of glucose for all temperatures and concentrationsare ranged from 0.061069943 to 0.062257803.

3.6. Temperature and Concentration Polynomial Empirical Equations of Enthalpy and Entropy of the Aqueous Honey and Aqueous Glucose/Insulin Solutions

The thermodynamics of viscous flow has been investigated by using the Eyring's viscosity equation, which is given as:

$$\eta = \left[\frac{N_A h}{V}\right] Exp\left[\frac{\Delta G}{RT}\right] \cdots\cdots\cdots (3.6.1)$$

Where h is Planck's constant, N_A is Avogadro's number and ΔG is the free energy of activation of viscous flow. The relationship between free energy ΔG, enthalpy ΔH, entropy ΔS and the equilibrium constant K of a viscous flow at a specific temperature T, is shown in equation (3.6.2) below. The Gas Constant, R, is equal to 8.314 J/mol·K.

$$\Delta G = -RTlnK = \Delta H - T\Delta S \cdots\cdots\cdots (3.6.2)$$

Equation (3.6.1) on combining with equation (3.6.2) gives the equation (Ali *et al.*, 2006):

$$Rln\left[\frac{\eta V}{hN_A}\right] = \left[\frac{\Delta H}{T}\right] - \Delta S \cdots\cdots\cdots (3.6.3)$$

A plot of Rln ($\eta V/hN_A$) versus 1/T should result in a straight line with a slope equal to the enthalpy ΔH and a y-axis intercept equal to the entropy ΔS. Figures (3.6.1) and (3.6.2) show the calculated entropy and enthalpy versus concentration of aqueous honey solutions.

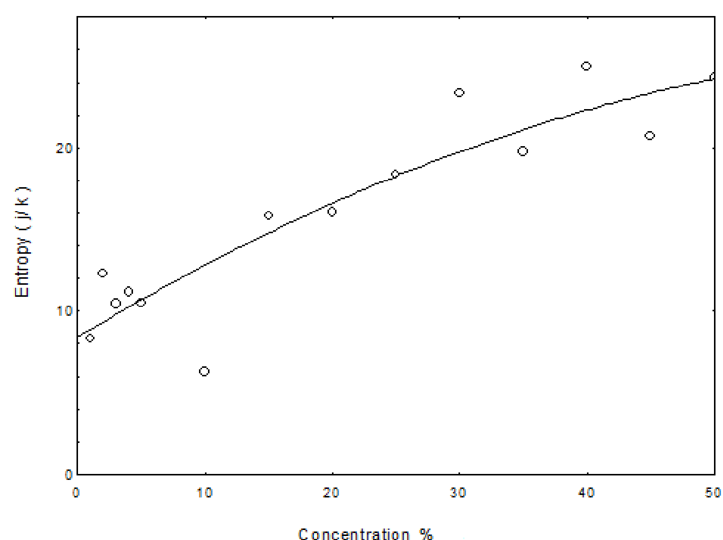


Figure (3.6.1): Entropy measured versus concentration for different temperatures of aqueous honey solutions.

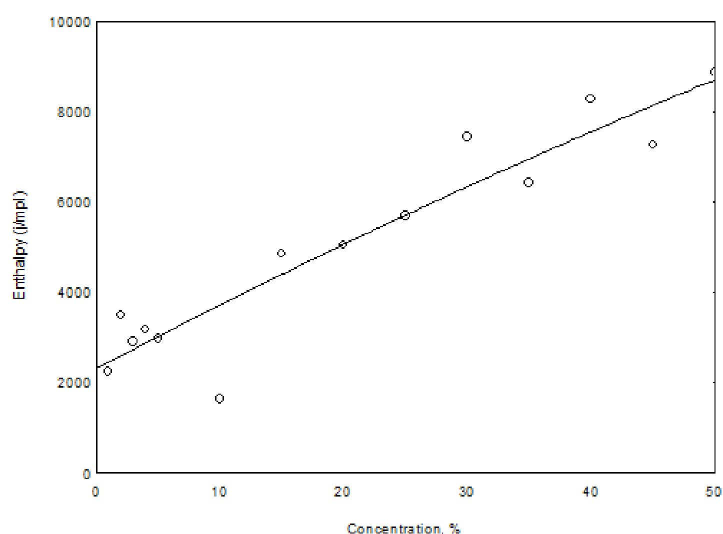


Figure (3.6.2): Enthalpy measured versus concentration for different temperatures of aqueous honey solutions.

From the previous figures (3.6.1) and (3.6.2) we can clearly see that the entropy and enthalpy increases with increasing honey concentration. The values of calculated entropy for aqueous honey solutions are ranged from $8.314JK^{-1}$ to $24.27JK^{-1}$. While, the values of calculated enthalpy for aqueous honey solutions are ranged from $2240Jmol^{-1}$ to $8864Jmol^{-1}$. The

effect of concentration on the entropy and enthalpy could be accurately fitted by the following polynomial equations:

$$\Delta S = A_{\Delta S} + B_{\Delta S}C + C_{\Delta S}C^2 \cdots\cdots\cdots (3.6.4)$$

$$\Delta H = A_{\Delta H} + B_{\Delta H}C + C_{\Delta H}C^2 \cdots\cdots\cdots (3.6.5)$$

The fitting constants $A_{\Delta S}$, $B_{\Delta S}$, $C_{\Delta S}$, $A_{\Delta H}$, $B_{\Delta H}$ and $C_{\Delta H}$ are given in tables (3.6.1-2) of aqueous honey solutions.

Table (3.6.1): The fitting constants of concentration polynomial model of entropy for all temperatures of aqueous honey solutions.

$A_{\Delta H}$	$B_{\Delta H}$	$C_{\Delta H}$	R^2
-3278	14420	3212	0.885

Table (3.6.2): The fitting constants of concentration polynomial model of enthalpy for all temperatures of aqueous honey solutions.

$A_{\Delta S}$	$B_{\Delta S}$	$C_{\Delta S}$	R^2
-31.04	47.13	8.416	0.832

3.7. Thermal Gradient and Concentration Increment of Reflectance and Transmittance of Normal Incidence Case of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

The reflectance R_λ from an air/medium interface in case of normal incidence can be written as (El-Zaiat, 2007):

$$R_\lambda = \left[\frac{n_\lambda - 1}{n_\lambda + 1}\right]^2 \cdots\cdots\cdots (3.7.1)$$

It indicates the ratio of the electromagnetic wave intensity reflected back from the sample interface to the incident wave intensity at different wavelengths λ.

The material transmittance T_λ through an air/medium interface in case of normal incidence can be written as (El-Zaiat, 2007):

$$T_\lambda = \frac{4n_\lambda}{[n_\lambda + 1]^2} \cdots\cdots\cdots (3.7.2)$$

It indicates the ratio of the transmitted electromagnetic wave intensity through the sample interface to the incident wave intensity at different wavelengths λ.

Figures (3.7.1-6) show the calculated reflectance and transmittance at sodium D spectral line (λ = 589nm) versus temperature for all concentrations of aqueous honey and aqueous glucose insulin solutions. While, figures (3.7.7-12) show the calculated reflectance and transmittance at sodium D spectral line (λ = 589nm) versus concentration for all temperatures of aqueous honey and aqueous glucose insulin solutions.

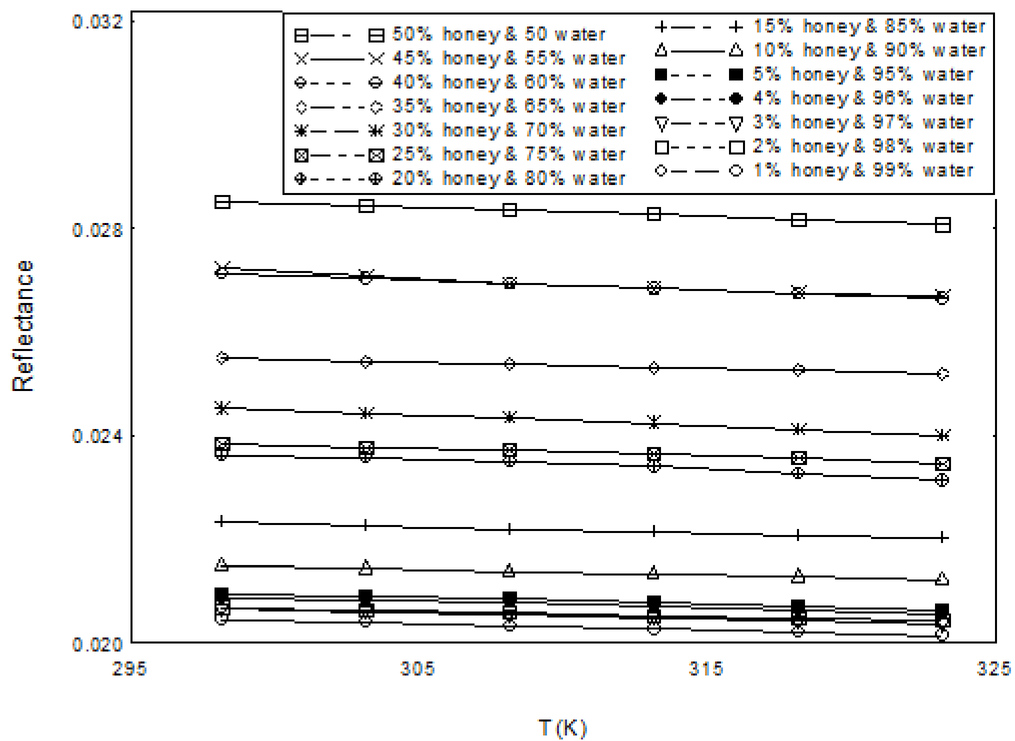


Figure (3.7.1): Reflectance measured versus temperature for different concentrations of aqueous honey solutions.

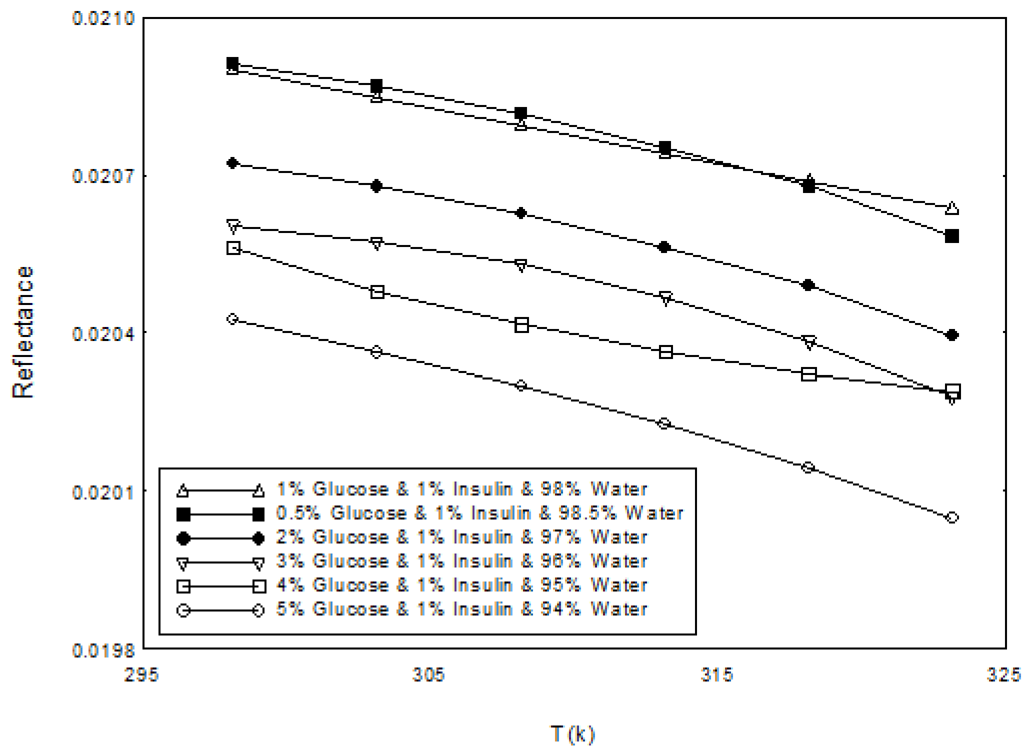


Figure (3.7.2): Reflectancemeasured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

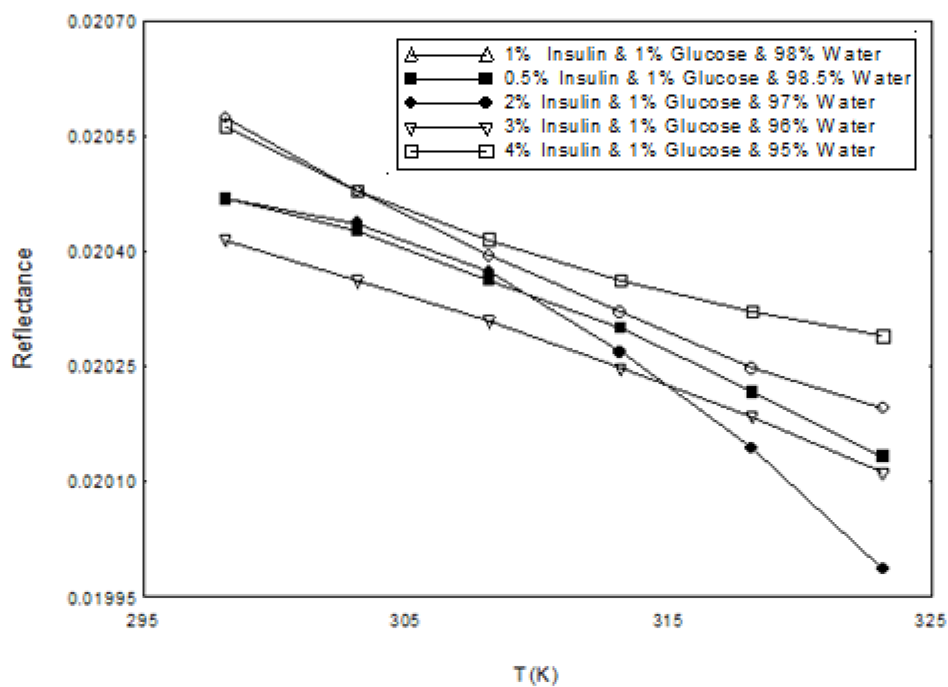


Figure (3.7.3): Reflectancemeasured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

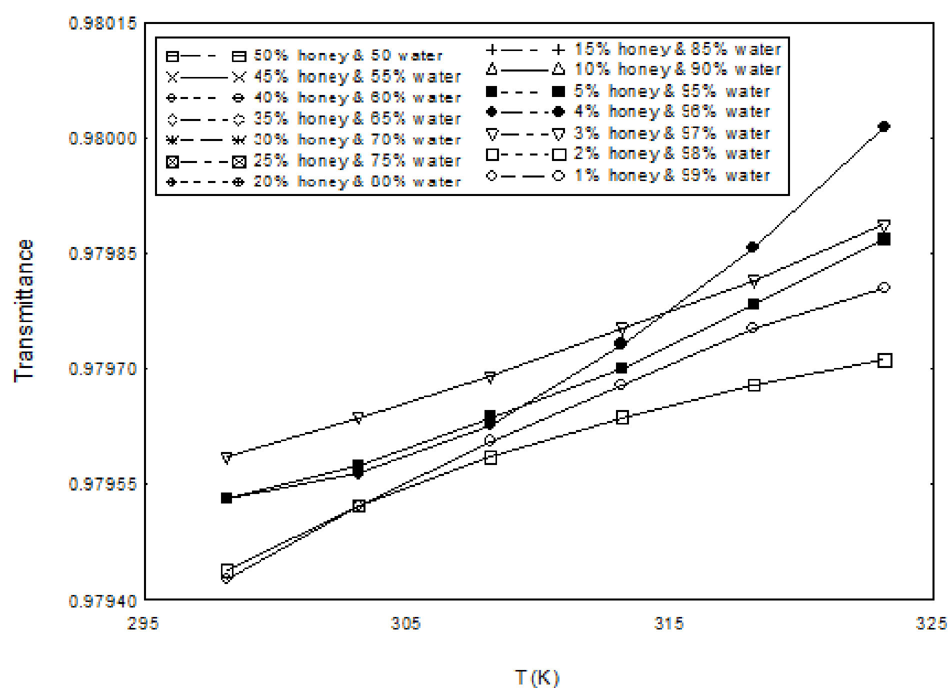


Figure (3.7.4): Transmittancemeasured versus temperature for different concentrations of aqueous honey solutions.

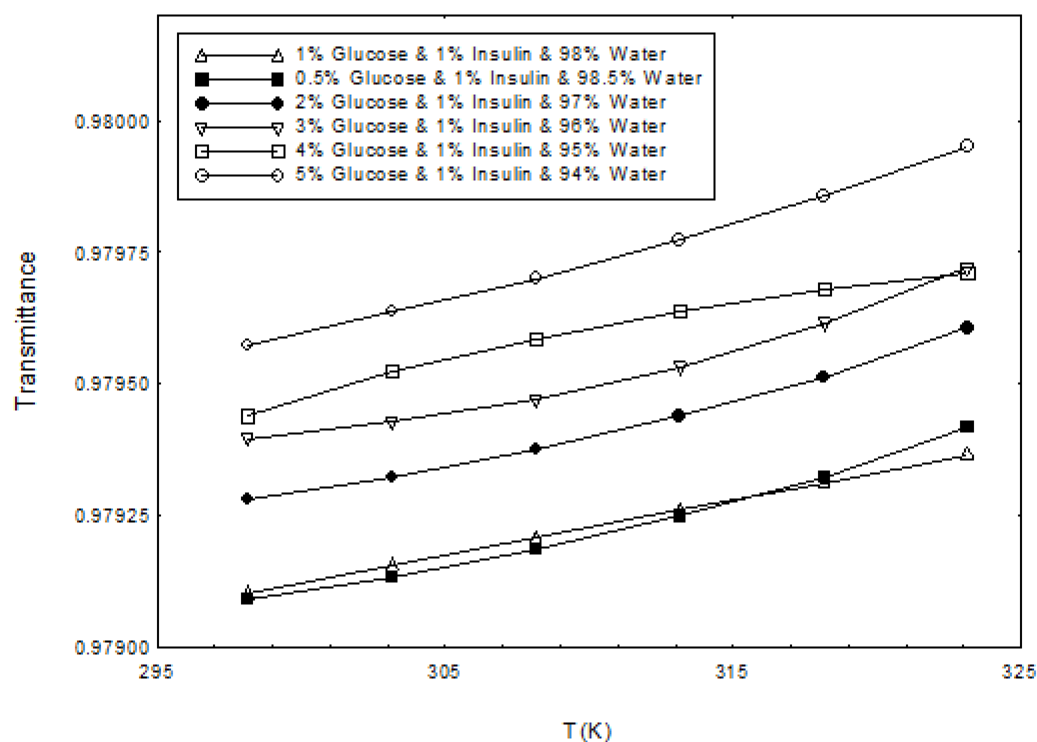


Figure (3.7.5): Transmittance measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

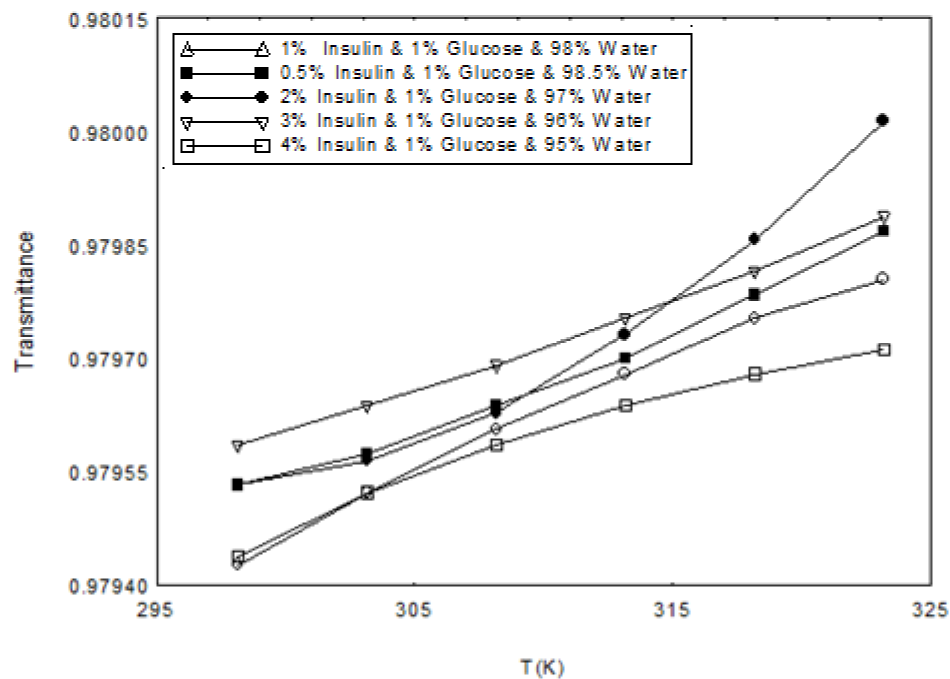


Figure (3.7.6): Transmittance measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

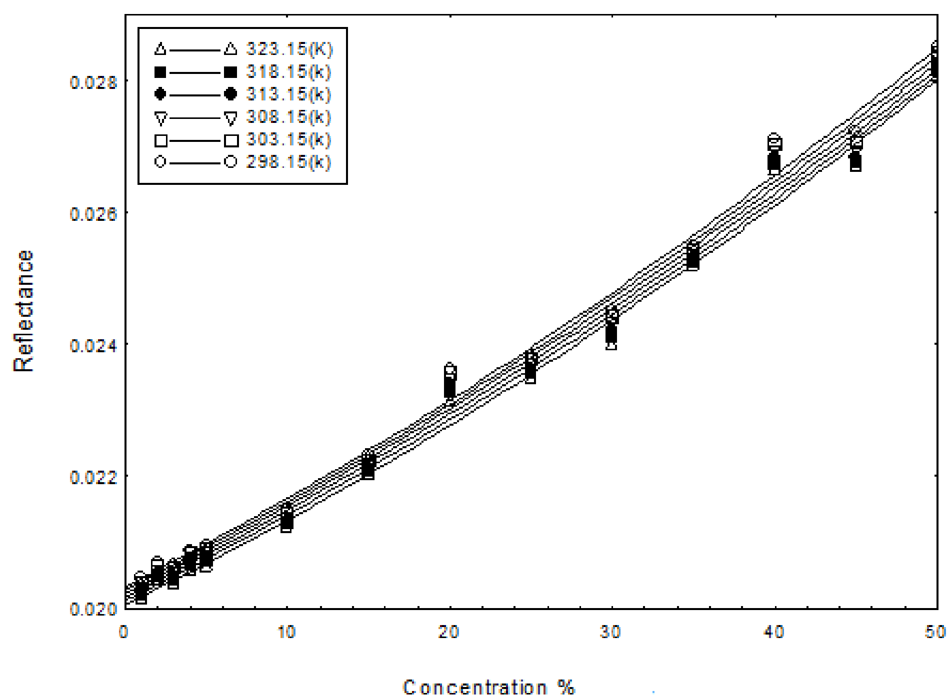


Figure (3.7.7): Reflectancemeasured versus concentration for different temperatures of aqueous honey solutions.

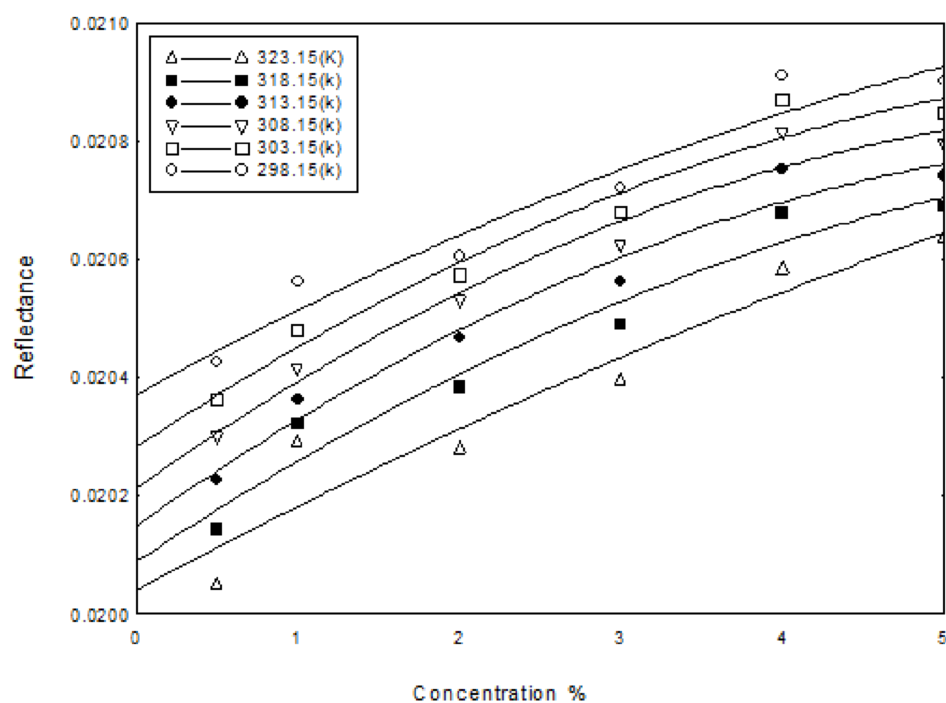


Figure (3.7.8): Reflectancemeasured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

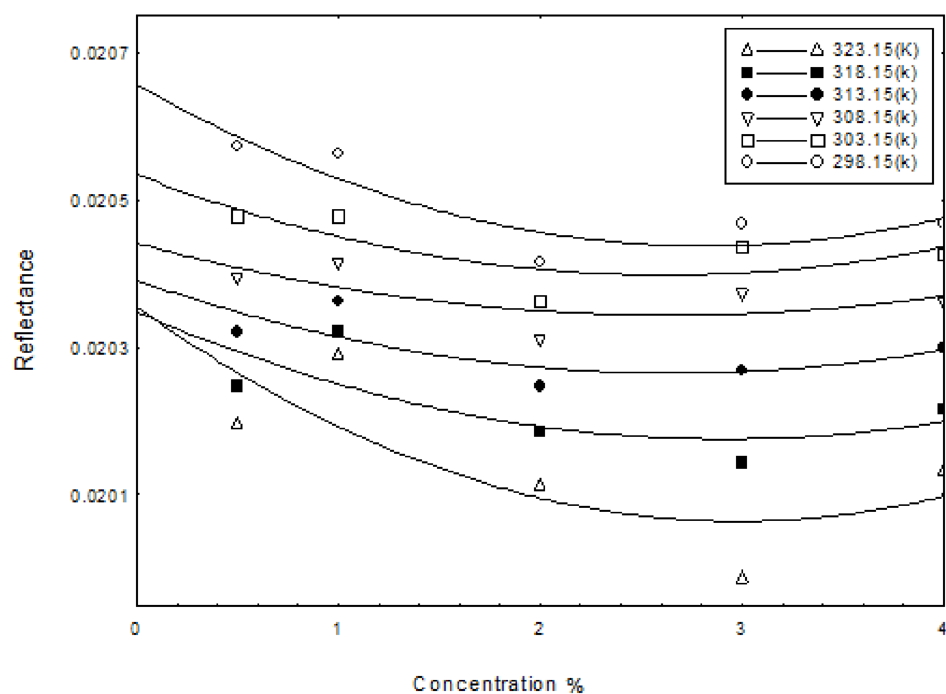


Figure (3.7.9): Reflectancemeasured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

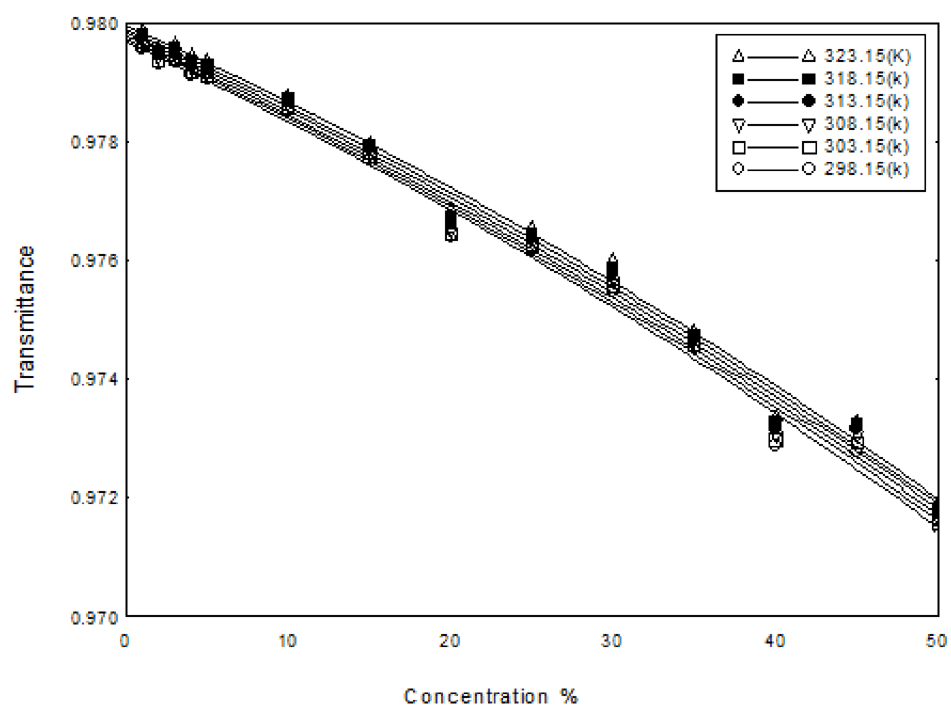


Figure (3.7.10): Transmittance measured versus concentration for different temperatures of aqueous honey solutions.

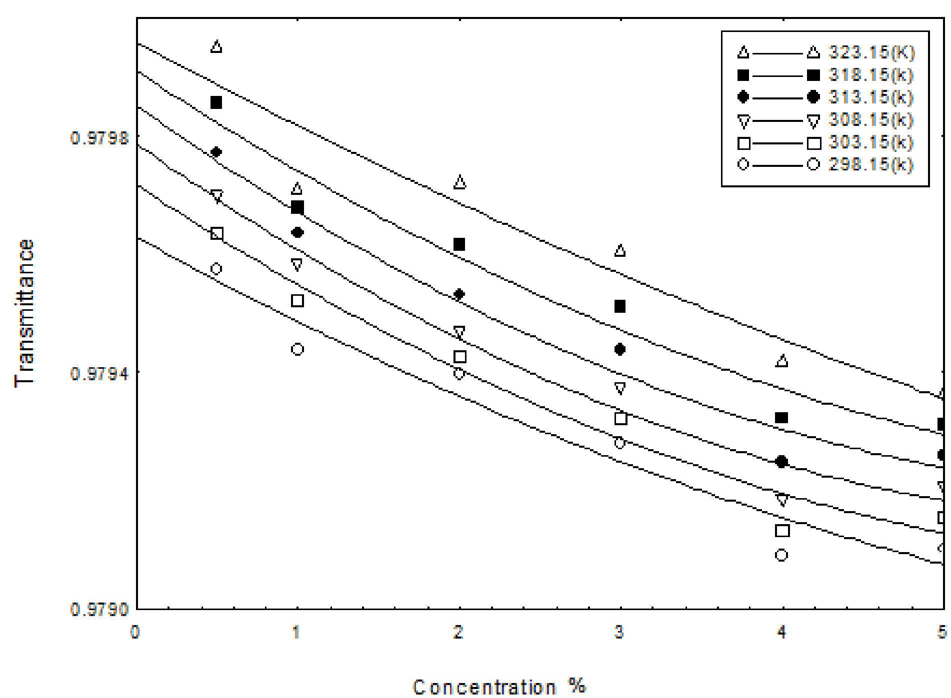


Figure (3.7.11): Transmittance measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

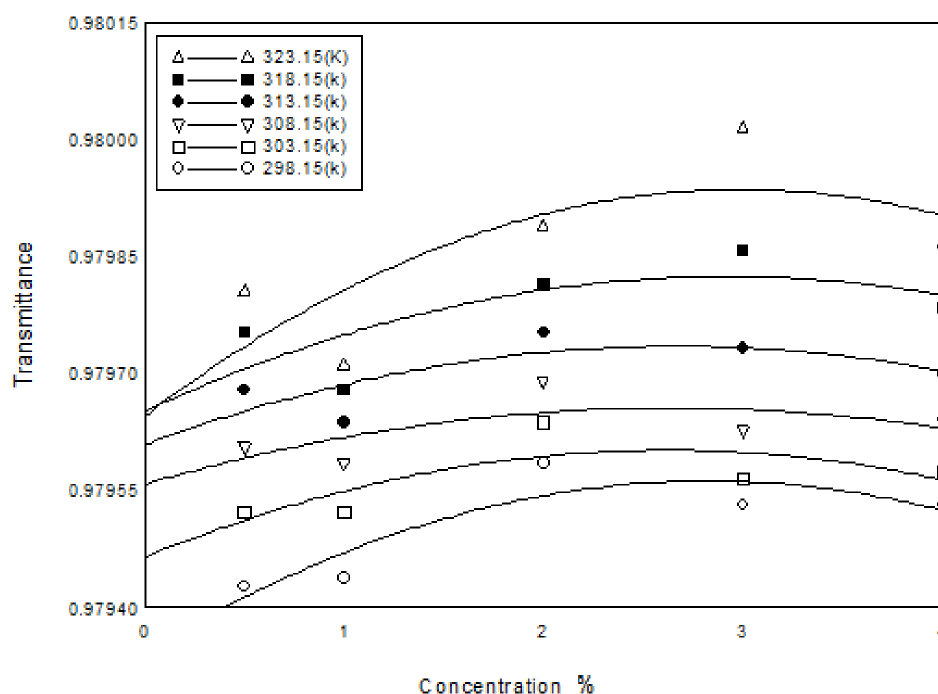


Figure (3.7.12): Transmittance measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

From figures (3.7.1) and (3.7.7) it is noticed that the reflectance is independent on temperature but increases linearly with increasing honey concentration. While, figures (3.7.4) and (3.7.10) show that the transmittanceis independent on temperature but decreased with increasing honey concentration. The values of reflectance of all aqueous honey samplesare ranged from 0.020143 to 0.028521. But, the values of transmittance of all aqueous honey samples ranged from 0.971479 to 0.979857. From figures (3.7.2) and (3.7.8) and it is seen that the reflectance linearly increases with increasing glucose concentration and decreases with increasing temperature. While, figures (3.7.5) and (3.7.11) show that the transmittance linearly decreased with increasing glucose concentration but increased with increasing temperature. The values of reflectance of aqueous glucose solutions mixed with one gram of insulin for all temperatures and concentrations are ranged from 0.020048878 to 0.020899909. But the values of transmittance of aqueous glucose

solutions mixed with one gram of insulin for all temperatures and concentrations are ranged from 0.979100091 to 0.979951122. From figures (3.7.3) and (3.7.9) it is noticed that the reflectance decreases with increasing insulin concentration and temperature. While, figures (3.7.6) and (3.7.12) show that the transmittance increases with increasing insulin concentration and temperature. The values of reflectance of aqueous insulin solutions mixed with one gram of glucose for all temperatures and concentrations are ranged from 0.0201324 to 0.0205728. But the values of transmittance of aqueous insulin solutions mixed with one gram of glucose for all temperatures and concentrations are ranged from 0.979427185 to 0.980013691. The effect of temperature and concentration on thenormal incidence reflectance could be accurately fitted by following polynomial equations:

$$R_\lambda = A_{oR} + B_{oR}T + C_{oR}T^2 \cdots\cdots\cdots \text{(3.7.3)}$$

$$R_\lambda = A_{oR} + B_{oR}C + C_{oR}C^2 \cdots\cdots\cdots \text{(3.7.4)}$$

The fitting constants A_{oR}, B_{oR}, and C_{oR} of the two previous equations are given in tables (3.7.1-6) for all samples of aqueous honey and aqueous glucose insulin solutions. While, the effect of temperature and concentration on thenormal incidence transmittance could be accurately fitted by following polynomial equations:

$$T_\lambda = A_{oT} + B_{oT}T + C_{oT}T^2 \cdots\cdots\cdots \text{(3.7.5)}$$

$$T_\lambda = A_{oT} + B_{oT}C + C_{oT}C^2 \cdots\cdots\cdots \text{(3.7.6)}$$

The fitting constants A_{oT}, B_{oT}, and C_{oT} of the two previous equations are given in tables (3.7.7-12) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.7.1): The fitting constants of temperature polynomial model of reflectance for all concentrations of aqueous honey solutions.

Concentration %	C_{oR} (k^{-2})	B_{oR} (k^{-1})	A_{oR}	R^2
1%	3.E-09	-1.E-05	0.0245	1
2%	3.E-08	-1.E-05	0.0267	0.9994
3%	-4.E-08	1.E-05	0.0207	1.00
4%	-2.E-07	1.E-04	0.0044	1.0000
5%	-2.E-07	1.E-04	0.0007	0.9997

Table (3.7.2): The fitting constants of temperature polynomial model of reflectance for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_{oR} (k^{-2})	B_{oR} (k^{-1})	A_{oR}	R^2
0.5%	-1.70E-07	9.07E-05	8.49E-03	1
1%	2.78E-07	-1.65E-04	4.77E-02	1
2%	-3.81E-07	2.24E-04	-1.23E-02	1
3%	-2.47E-07	1.40E-04	8.07E-04	1
4%	-2.47E-07	1.41E-04	9.35E-04	1
5%	8.90E-10	1.11E-05	2.41E-02	1

Table (3.7.3): The fitting constants of temperature polynomial model of reflectance For all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_{oR} (k^{-2})	B_{oR} (k^{-1})	A_{oR}	R^2
0.5%	1.82E-07	-1.28E-04	4.26E-02	1
1%	2.48E-07	-1.65E-04	4.77E-02	1
2%	-1.04E-07	5.22E-05	1.40E-02	1
3%	-6.25E-07	3.69E-04	3.40E-02	1
4%	-2.08E-07	1.16E-04	4.45E-03	1

Table (3.7.4): The fitting constants of concentration polynomial model of reflectance for all temperatures of aqueous honey solutions.

T(K)	C_{oR}	B_{oR}	A_{oR}	R^2
298.15 (k)	0.0073	0.0127	0.0203	0.9924
303.15 (k)	0.0071	0.0126	0.0203	0.9918
308.15 (k)	0.0069	0.0126	0.0202	0.9914
313.15 (k)	0.0070	0.0125	0.0202	0.9917
318.15 (k)	0.0073	0.0123	0.0201	0.992
323.15 (k)	0.0077	0.0120	0.0201	0.9927

Table (3.7.5): The fitting constants of concentration polynomial model of reflectance for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_{oR}	B_{oR}	A_{oR}	R
298.15	-0.080	0.0151	2.037E-02	0.948
303.15	-0.128	0.0182	2.028E-02	0.965
308.15	-0.148	0.0195	2.021E-02	0.970
313.15	-0.145	0.0195	2.015E-02	0.969
318.15	-0.117	0.0182	2.009E-02	0.957
323.15	-0.051	0.0146	2.004E-02	0.915

Table (3.7.6): The fitting constants of concentration polynomial model of reflectance for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_{oR}	B_{oR}	A_{oR}	R^2
298.15 (k)	-0.263	0.018	0.020	1
303.15 (k)	-0.420	0.028	0.020	1
308.15 (k)	-0.367	0.025	0.020	1
313.15 (k)	0.052	-0.001	0.020	1
318.15 (k)	0.575	-0.033	0.021	1
323.15 (k)	1.356	-0.080	0.021	1

Table (3.7.7): The fitting constants of temperature polynomial model of transmittance for all concentrations of aqueous honey solutions.

Concentration %	C_{oT} (k^{-2})	B_{oT} (k^{-1})	A_{oT}	R^2
1%	-3.E-09	1.E-05	0.9755	1.0000
2%	-3.E-08	3.E-05	0.9733	0.9994
3%	4.E-08	-1.E-05	0.9793	0.9996
4%	2.E-07	-1.E-04	0.9956	1.0000
5%	2.E-07	-1.E-04	0.9993	0.9997

Table (3.7.8): The fitting constants of temperature polynomial model of transmittance for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	C_{oT} (k^{-2})	B_{oT} (k^{-1})	A_{oT}	R^2
0.5%	1.70E-07	-9.07E-05	0.99	1
1%	-2.48E-07	1.65E-04	0.95	1
2%	3.81E-07	-2.24E-05	1.01	1
3%	2.47E-07	-1.40E-04	0.999	1
4%	2.47E-07	-1.41E-04	0.999	1
5%	-8.90E-10	1.11E-05	0.976	1

Table (3.7.9): The fitting constants of temperature polynomial model of transmittance for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_{oT} (k^{-2})	B_{oT} (k^{-1})	A_{oT}	R^2
0.5%	-1.82E-07	1.28E-04	0.9570	1
1%	-2.48E-07	1.65E-04	0.9520	1
2%	1.04E-07	-5.22E-05	0.9860	1
3%	6.25E-07	-3.69E-04	1.0300	1
4%	2.08E-09	-1.16E-04	0.9960	1

Table (3.7.10): The fitting constants of concentration polynomial model of transmittance for all temperatures of aqueous honey solutions.

T(K)	C_{oT}	B_{oT}	A_{oT}	R^2
298.15 (k)	-0.0073	-0.0127	0.9797	0.9924
303.15 (k)	-0.0069	-0.0126	0.9797	0.9918
308.15 (k)	-0.0071	-0.0126	0.9798	0.9914
313.15 (k)	-0.007	-0.0125	0.9798	0.9917
318.15 (k)	-0.0073	-0.0123	0.9799	0.992
323.15 (k)	-0.0077	-0.012	0.9799	0.9927

Table (3.7.11): The fitting constants of concentration polynomial model of transmittance for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_{oT}	B_{oT}	A_{oT}	R
298.15	7.98E-02	-1.51E-02	0.980	0.948
303.15	1.28E-01	-1.82E-02	0.980	0.965
308.15	1.48E-01	-1.95E-02	0.980	0.970
313.15	1.45E-01	-1.95E-02	0.980	0.969
318.15	1.17E-01	-1.82E-02	0.980	0.957
323.15	5.08E-02	-1.46E-02	0.980	0.915

Table (3.7.12): The fitting constants of concentration polynomial model of transmittance for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_{oT}	B_{oT}	A_{oT}	R^2
298.15 (k)	0.263	-0.018	0.980	1
303.15 (k)	0.420	-0.028	0.980	1
308.15 (k)	0.367	-0.025	0.980	1
313.15 (k)	-0.052	0.001	0.980	1
318.15 (k)	-0.575	0.033	0.979	1
323.15 (k)	-1.356	0.080	0.979	1

The derivative to temperature of the temperature polynomial equation (3.7.3) and the derivative to concentration of the concentration polynomial equation (3.7.4) give the following thermal gradient dR_λ/dT and concentration increment dR_λ/dC of normal incidence reflectance:

$$\frac{dR_\lambda}{dT} = A_R + B_R T + C_R T^2 \cdots\cdots\cdots (3.7.7)$$

$$\frac{dR_\lambda}{dC} = A_R + B_R C + \mathrm{AR}C^2 \cdots\cdots\cdots (3.7.8)$$

The fitting constants A_R, B_R, and C_R of the two previous equations are given in tables (3.7.13-18) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.7.13): The fitting constants of temperature polynomial model of temperature gradient of reflectance for all concentrations of aqueous honey solutions.

Concentration %	A_R (k^{-1})	B_R (k^{-2})	C_R	R^2
1%	-1.E-05	6.00E-09	0	1
2%	-1.E-05	6.00E-08	0	1
3%	1.E-05	-8.00E-08	0	1
4%	1.E-04	-4.00E-07	0	1
5%	1.E-04	-4.00E-07	0	1

Table (3.7.14): The fitting constants of temperature polynomial model of temperature gradient of reflectance for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_R (k^{-1})	B_R (k^{-2})	C_R	R^2
0.5%	9.07E-05	-3.40E-07	0	1
1%	-1.65E-04	5.56E-07	0	1
2%	2.24E-04	-7.62E-07	0	1
3%	1.40E-04	-4.94E-07	0	1
4%	1.41E-04	-4.94E-07	0	1
5%	1.11E-05	1.78E-09	0	1

Table (3.7.15): The fitting constants of temperature polynomial model of temperature gradient of reflectance for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_R (k^{-1})	B_R (k^{-2})	C_R	R^2
0.5%	-1.28E-04	3.64E-07	0	1
1%	-1.65E-04	4.96E-07	0	1
2%	5.22E-05	-2.08E-07	0	1
3%	3.69E-04	-1.25E-06	0	1
4%	1.16E-04	-4.16E-07	0	1

Table (3.7.16): The fitting constants of concentration polynomial model of concentration increment of reflectance for all temperatures of aqueous honey solutions.

T(K)	A_R	B_R	C_R	R^2
298.15 (k)	0.0127	1.46E-02	0	1
303.15 (k)	0.0126	1.42E-02	0	1
308.15 (k)	0.0126	1.38E-02	0	1
313.15 (k)	0.0125	1.40E-02	0	1
318.15 (k)	0.0123	1.46E-02	0	1
323.15 (k)	0.0120	1.54E-02	0	1

Table (3.7.17): The fitting constants of concentration polynomial model of concentration increment of reflectance for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_R	B_R	C_R	R^2
298.15 (k)	0.0151	-1.60E-01	0	1
303.15 (k)	0.0182	-2.56E-01	0	1
308.15 (k)	0.0195	-2.96E-01	0	1
313.15 (k)	0.0195	-2.90E-01	0	1
318.15 (k)	0.0182	-2.34E-01	0	1
323.15 (k)	0.0146	-1.02E-01	0	1

Table (3.7.18): The fitting constants of concentration polynomial model of concentration increment of reflectance for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_R	B_R	C_R	R^2
298.15 (k)	0.018	-5.26E-01	0	1
303.15 (k)	0.028	-8.40E-01	0	1
308.15 (k)	0.025	-7.34E-01	0	1
313.15 (k)	-0.001	1.04E-01	0	1
318.15 (k)	-0.033	1.15E+00	0	1

The derivative to temperature of the temperature polynomial equation (3.7.5) and the derivative to concentration of the concentration polynomial equation (3.7.6) give the following thermal gradient dT_λ/dT and concentration increment dT_λ/dC of normal incidence transmittance:

$$\frac{dT_\lambda}{dT} = A_T + B_T T + C_T T^2 \cdots\cdots\cdots \text{(3.7.7)}$$

$$\frac{dT_\lambda}{dC} = A_T + B_T C + C_T C^2 \cdots\cdots\cdots \text{(3.7.8)}$$

The fitting constants A_T, B_T, and C_T of the two previous equations are given in tables (3.7.19-24) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.7.19): The fitting constants of temperature polynomial model of temperature gradient of transmittance for all concentrations of aqueous honey solutions.

Concentration %	A_T (k^{-1})	B_T (k^{-2})	C_T	R^2
1%	1.E-05	-6.E-09	0	1
2%	3.E-05	-6.E-08	0	1
3%	-1.E-05	8.E-08	0	1
4%	-1.E-04	4.E-07	0	1
5%	-1.E-04	4.E-07	0	1

Table (3.7.20): The fitting constants of temperature polynomial model of temperature gradient of transmittance for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_T (k^{-1})	B_T (k^{-2})	C_T	R^2
0.5%	-9.07E-05	3.E-07	0	1
1%	1.65E-04	-5.E-07	0	1
2%	-2.24E-05	8.E-07	0	1
3%	-1.40E-04	5.E-07	0	1
4%	-1.41E-04	5.E-07	0	1
5%	1.11E-05	3.E-07	0	1

Table (3.7.21): The fitting constants of temperature polynomial model of temperature gradient of transmittance for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_T (k^{-1})	B_T (k^{-2})	C_T	R^2
0.5%	1.28E-04	-4.E-07	0	1
1%	1.65E-04	-5.E-07	0	1
2%	-5.22E-05	2.E-07	0	1
3%	-3.69E-04	1.E-06	0	1
4%	-1.16E-04	4.E-09	0	1

Table (3.7.22): The fitting constants of concentration polynomial model of concentration increment of transmittance for all temperatures of aqueous honey solutions.

T(K)	A_T	B_T	C_T	R^2
298.15 (k)	-0.0127	-1.46E-02	0	1
303.15 (k)	-0.0126	-1.38E-02	0	1
308.15 (k)	-0.0126	-1.42E-02	0	1
313.15 (k)	-0.0125	-1.40E-02	0	1
318.15 (k)	-0.0123	-1.46E-02	0	1
323.15 (k)	-0.012	-1.54E-02	0	1

Table (3.7.23): The fitting constants of concentration polynomial model of concentration increment of transmittance for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_T	B_T	C_T	R^2
298.15 (k)	-1.51E-02	0.160	0	1
303.15 (k)	-1.82E-02	0.256	0	1
308.15 (k)	-1.95E-02	0.296	0	1
313.15 (k)	-1.95E-02	0.290	0	1
318.15 (k)	-1.82E-02	0.234	0	1
323.15 (k)	-1.46E-02	0.102	0	1

Table (3.7.24): The fitting constants of concentration polynomial model of concentration increment of transmittance for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_T	B_T	C_T	R^2
298.15 (k)	-0.018	0.526	0	1
303.15 (k)	-0.028	0.840	0	1
308.15 (k)	-0.025	0.734	0	1
313.15 (k)	0.001	-0.104	0	1
318.15 (k)	0.033	-1.150	0	1
323.15 (k)	0.080	-2.712	0	1

3.8. Thermal Gradient and Concentration Increment of Optical Permittivity and Reflection Factor of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

In electromagnetism, electric permittivity ε is the measure of the resistance that is encountered when forming an electric field in a medium. In other words, permittivity is a measure of how an electric field affects, and is affected by, a dielectric medium. At optical high frequencies the permittivity of a material cannot be measured by the use of electrical methods. However, it is known from Maxwell's theory in electromagnetic waves that for non-magnetic materials permittivity is related to the refractive index as follows (Tekin and Tarimci, 2006):

$$\varepsilon = n_{\lambda}^{2} \cdots\cdots\cdots (3.8.1)$$

Using the data of refractive index n_λ and according to Maxwell's theory for a transparent nonmagnetic materials (permeability ≈ 1), optical permittivity εcan be calculate at the mentioned sodium D spectral line (λ = 589nm). Figures (3.8.1-6) show the calculated values of optical permittivity versus temperature and versus concentration respectively for samples of aqueous honey and aqueous glucose insulin solutions.

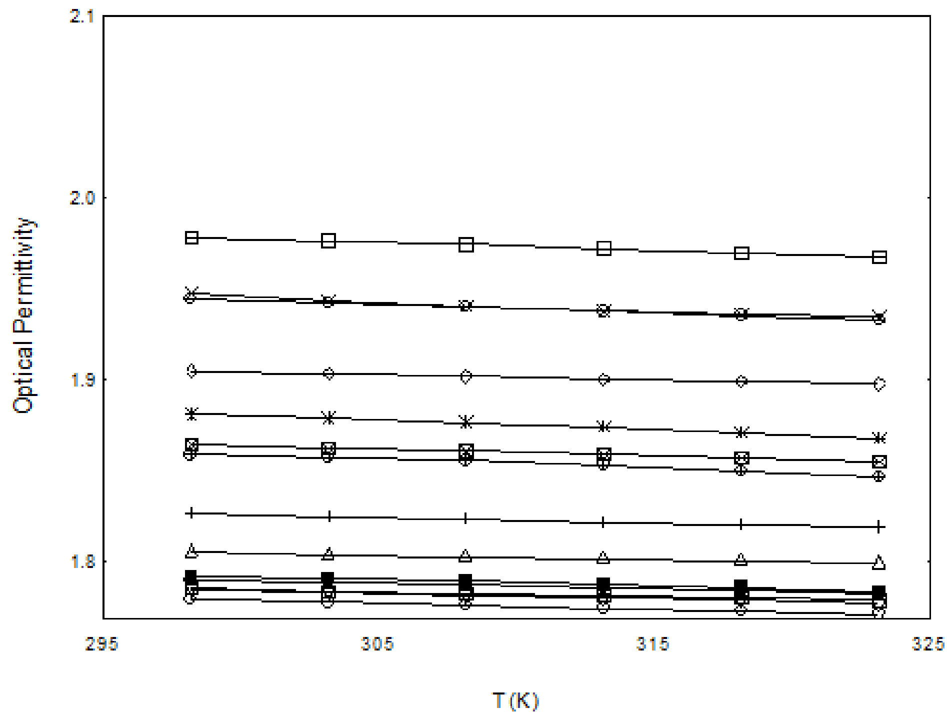


Figure (3.8.1): Optical Permittivity measured versus temperature for different concentrations of aqueous honey solutions.

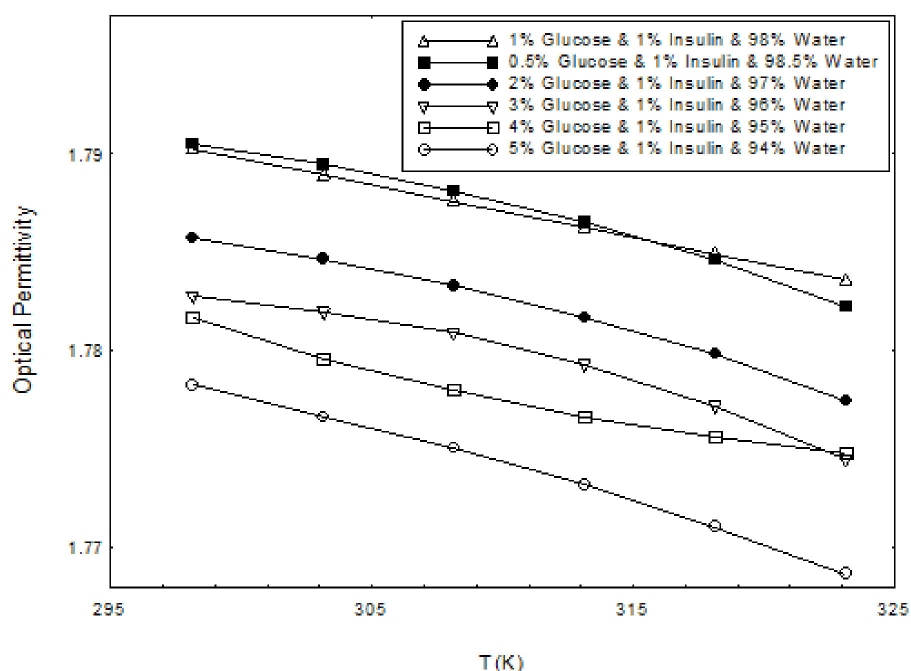


Figure (3.8.2): Optical Permittivity measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

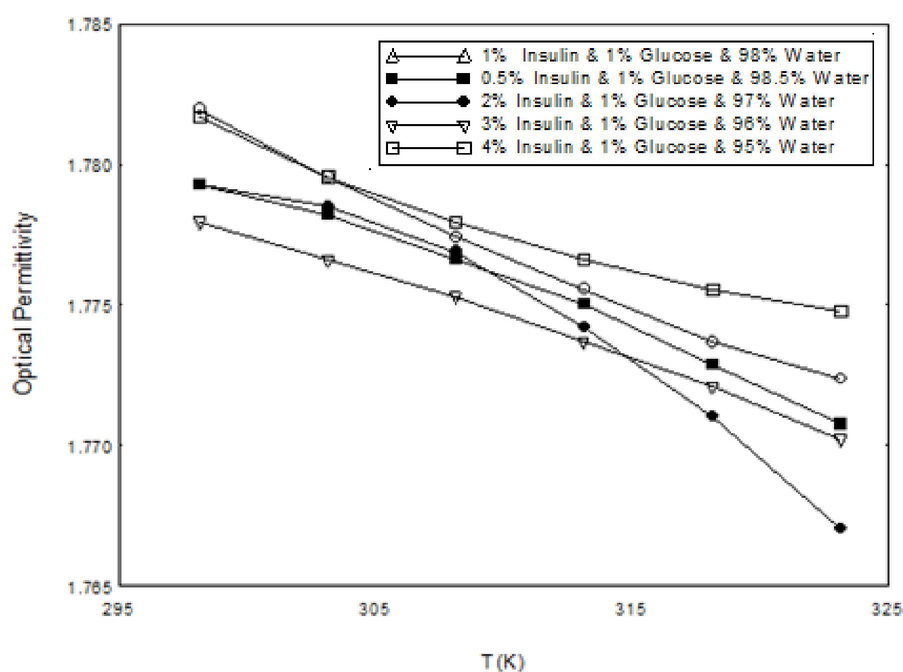


Figure (3.8.3): Optical Permittivity measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

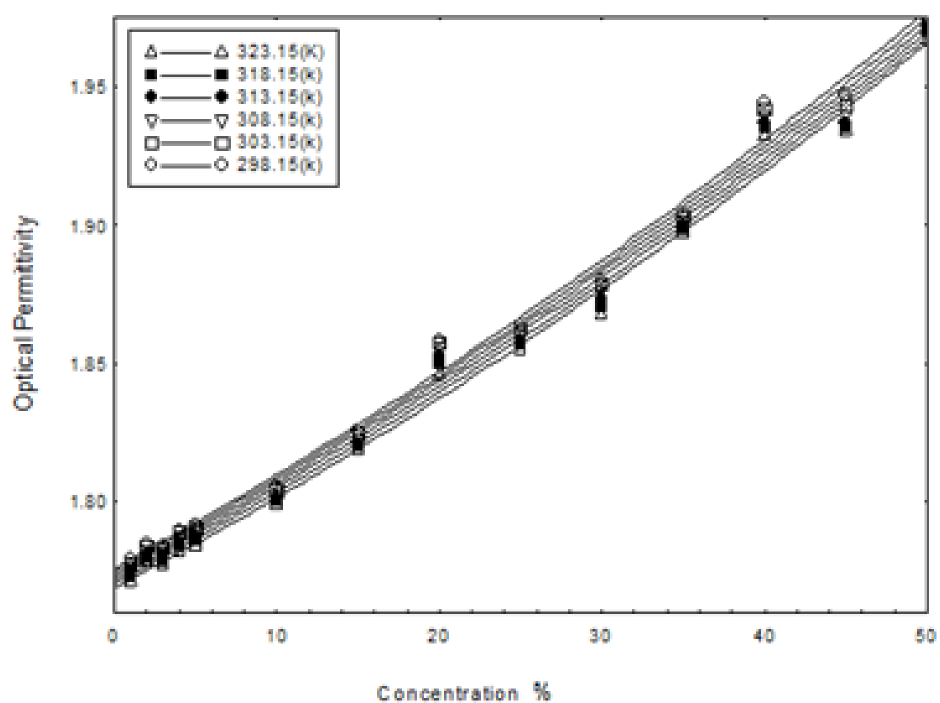


Figure (3.8.4): Optical Permittivity measured versus concentration for different temperatures of aqueous honey solutions.

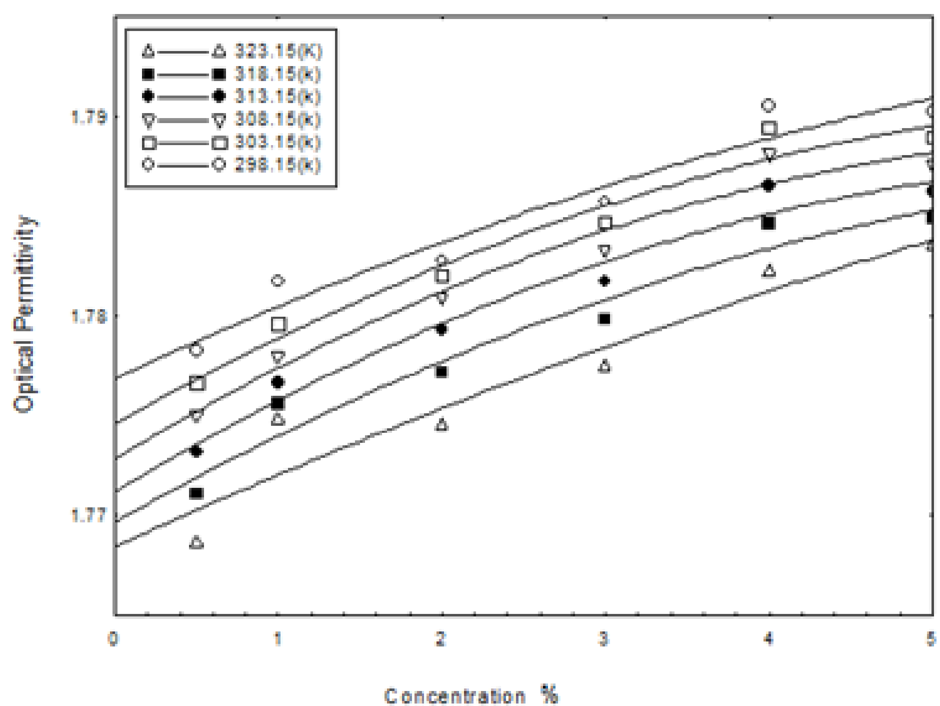


Figure (3.8.5): Optical Permittivity measured versus concentration for different temperatures of aqueous honey solutions.

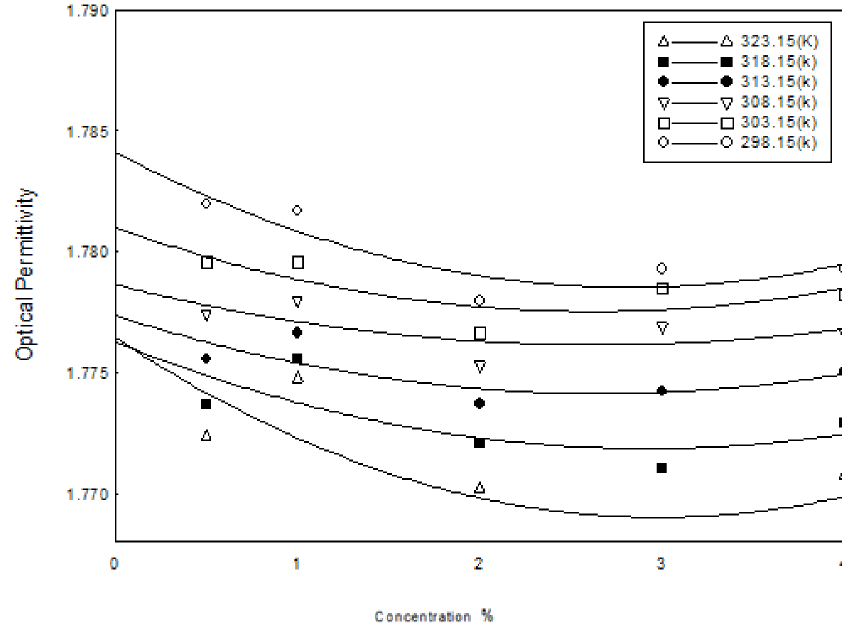


Figure (3.8.6): Optical Permittivity measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

From figures (3.8.1) and (3.8.4) it is noticed that the optical permittivity is independent on temperature but increases with increasing honey concentration. The values of optical permittivity for all temperatures and all honey concentrations of aqueous honey solutions are ranged from 1.771029 to 1.977961. Figures (3.8.2) and (3.8.5) show that the optical permittivity increases with increasing glucose concentration but decreases with increasing temperature. The values of optical permittivity for all temperatures and all glucose concentrations of aqueous glucose solutions mixed with one gram of insulin are ranged from 1.76863401 to 1.790244. Figures (3.8.3) and (3.8.6) show that the optical permittivity decreases with increasing insulin concentration and decreases with increasing temperature. The values of optical permittivity for all temperatures and all insulin concentrations of aqueous insulin solutions mixed with one gram of glucoseare ranged from 1.76703849 to 1.78195801.

The effect of temperature and concentration on theoptical permittivity could be accurately fitted by following polynomial equations:

$$\varepsilon = A_{o\varepsilon} + B_{o\varepsilon} T + C_{o\varepsilon} T^2 \cdots\cdots\cdots (3.8.2)$$

$$\varepsilon = A_{o\varepsilon} + B_{o\varepsilon} C + C_{o\varepsilon} C^2 \cdots\cdots\cdots (3.8.3)$$

The fitting constants $A_{o\varepsilon}$, $B_{o\varepsilon}$, and $C_{o\varepsilon}$ of the two previous equations are given in tables (3.8.1-6) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.8.1): The fitting constants of temperature polynomial model of optical permittivity for all concentrations of aqueous honey solutions.

Concentration %	$C_{o\varepsilon}$ (k^{-2})	$B_{o\varepsilon}$ (k^{-1})	$A_{o\varepsilon}$	R^2
1%	1.E-08	-3.00E-04	1.8757	1.0000
2%	8.E-07	-7.00E-04	1.9353	0.9994
3%	-9.E-07	3.00E-04	1.7829	0.9996
4%	-5.E-06	3.00E-03	1.3715	1.0000
5%	-6.E-06	3.60E-03	1.2787	0.9997

Table (3.8.2): The fitting constants of temperature polynomial model of optical permittivity for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	$C_{o\varepsilon}$ (k^{-2})	$B_{o\varepsilon}$ (k^{-1})	$A_{o\varepsilon}$	R^2
0.5%	-4.36E-06	2.33E-03	1.47	1
1%	6.30E-06	-4.19E-03	2.47	1
2%	-4.36E-06	5.70E-03	0.0946	1
3%	-6.28E-06	3.57E-03	1.280	1
4%	-6.29E-06	3.58E-03	1.280	1
5%	1.00E-08	-2.74E-04	1.870	1

Table (3.8.3): The fitting constants of temperature polynomial model of optical permittivity for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	$C_{o\varepsilon}$ (k^{-2})	$B_{o\varepsilon}$ (k^{-1})	$A_{o\varepsilon}$	R^2
0.5%	4.59E-06	-3.24E-03	2.34	1
1%	6.30E-06	-4.19E-03	2.47	1
2%	-2.65E-06	1.34E-03	1.61	1
3%	-1.60E-05	9.42E-03	3.90	1
4%	-5.31E-05	2.96E-03	1.37	1

T(K)	$C_{o\varepsilon}$	$B_{o\varepsilon}$	$A_{o\varepsilon}$	R^2

Table (3.8.4): The fitting constants of concentration polynomial model of optical permittivity for all temperatures of aqueous honey solutions.

T(K)	$C_{o\varepsilon}$	$B_{o\varepsilon}$	$A_{o\varepsilon}$	R^2
298.15 (k)	0.1593	0.3238	1.757	0.9925
303.15 (k)	0.1556	0.3224	1.7745	0.9919
308.15 (k)	0.1506	0.3226	1.7731	0.9916
313.15 (k)	0.1526	0.3195	1.7717	0.9918
318.15 (k)	0.161	0.3141	1.7703	0.9921
323.15 (k)	0.1708	0.3085	1.7688	0.9928

T(K)	$C_{o\varepsilon}$	$B_{o\varepsilon}$	$A_{o\varepsilon}$	R^2
298.15	-2.030	0.380	1.780	0.950
303.15	-3.250	0.460	1.770	0.970
308.15	-3.780	0.500	1.773	0.970
313.15	-3.691	0.496	1.771	0.978
318.15	-2.990	0.463	1.770	0.957
323.15	-1.308	0.373	1.768	0.915

Table (3.8.5): The fitting constants of concentration polynomial model of optical permittivity for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

Table (3.8.6): The fitting constants of concentration polynomial model of optical permittivity for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

298.15 (k)	-6.668	0.467	1.771	1
303.15 (k)	-10.666	0.720	1.766	1
308.15 (k)	-9.329	0.626	1.766	1
313.15 (k)	1.333	-0.013	1.733	1
318.15 (k)	14.642	-0.839	1.783	1
323.15 (k)	34.579	-2.048	1.797	1

The derivativeto temperature of the temperature polynomial equation (3.8.2) and the derivative to concentration of the concentration polynomial equation (3.8.3) give the following thermal gradient dε/dT and concentration increment dε/dC of optical permittivity:

$$\frac{d\varepsilon}{dT} = A_\varepsilon + B_\varepsilon T + C_\varepsilon T^2 \cdots\cdots\cdots (3.8.4)$$

$$\frac{d\varepsilon}{dC} = A_\varepsilon + B_\varepsilon C + C_\varepsilon C^2 \cdots\cdots\cdots (3.8.5)$$

The fitting constants A_ε, B_ε, and C_ε of the two previous equations are given in tables (3.7.7-12) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.8.7): The fitting constants of temperature polynomial model of temperature gradient of optical permittivity for all concentrations of aqueous honey solutions.

Concentration %	A_ε (k^{-1})	B_ε (k^{-2})	C_ε	R^2
1%	-3.00E-04	2.E-08	0	1
2%	-7.00E-04	2.E-06	0	1
3%	3.00E-04	-2.E-06	0	1
4%	3.00E-03	-1.E-05	0	1
5%	3.60E-03	-1.E-05	0	1

Table (3.8.8): The fitting constants of temperature polynomial model of temperature gradient of optical permittivity for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration	A_ε	B_ε	C_ε	R^2

%	(k^{-1})	(k^{-2})		
0.5%	2.33E-03	-9.E-06	0	1
1%	-4.19E-03	1.E-05	0	1
2%	5.70E-03	-9.E-06	0	1
3%	3.57E-03	-1.E-05	0	1
4%	3.58E-03	-1.E-05	0	1
5%	-2.74E-04	-9.E-06	0	1

Table (3.8.9): The fitting constants of temperature polynomial model of temperature gradient of optical permittivity for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_ε (k^{-1})	B_ε (k^{-2})	C_ε	R^2
0.5%	-3.24E-03	9.18E-06	0	1
1%	-4.19E-03	1.26E-05	0	1
2%	1.34E-03	-5.30E-06	0	1
3%	9.42E-03	-3.20E-05	0	1
4%	2.96E-03	-1.06E-04	0	1

Table (3.8.10): The fitting constants of concentration polynomial model of optical permittivity for all temperatures of aqueous honey solutions.

T(K)	A_ε	B_ε	C_ε	R^2
298.15 (k)	0.3238	3.19E-01	0	1
303.15 (k)	0.3224	3.11E-01	0	1
308.15 (k)	0.3226	3.01E-01	0	1
313.15 (k)	0.3195	3.05E-01	0	1
318.15 (k)	0.3141	3.22E-01	0	1
323.15 (k)	0.3085	3.42E-01	0	1

Table (3.8.11): The fitting constants of concentration polynomial model of optical permittivity for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_ε	B_ε	C_ε	R^2
298.15 (k)	0.380	-4.06	0	1

303.15 (k)	0.460	-6.50	0	1
308.15 (k)	0.500	-7.56	0	1
313.15 (k)	0.496	-7.38	0	1
318.15 (k)	0.463	-5.98	0	1
323.15 (k)	0.373	-2.62	0	1

Table (3.8.12): The fitting constants of concentration polynomial model of optical permittivity for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_ε	B_ε	C_ε	R^2
298.15 (k)	0.467	-13.33	0.467	1
303.15 (k)	0.720	-21.33	0.72	1
308.15 (k)	0.626	0.626	0	1
313.15 (k)	-0.013	-0.013	0	1
318.15 (k)	-0.839	29.28	-0.839	1
323.15 (k)	-2.048	69.15	-2.048	1

Reflectionfactorδ_λ is ameasureoftheabilityofasurfacetoreflectlightorotherelectromagneticradiation, equaltotheratioofthereflectedflux to the incidentflux. Reflection factor can be determined through refractive index n_λ or through normal incidence reflectance $R_\lambda$by using the following relation:

$$\delta_\lambda = \frac{2n_\lambda}{n_\lambda^2 + 1} = \frac{[1 - R_\lambda]^2}{[1 - R_\lambda^2]} \cdots\cdots\cdots (3.8.6)$$

Figures (3.8.7-12) show the calculated values of reflection factor versus temperature and versus concentration respectively for all samples of aqueous honey and aqueous glucose insulin solutions.

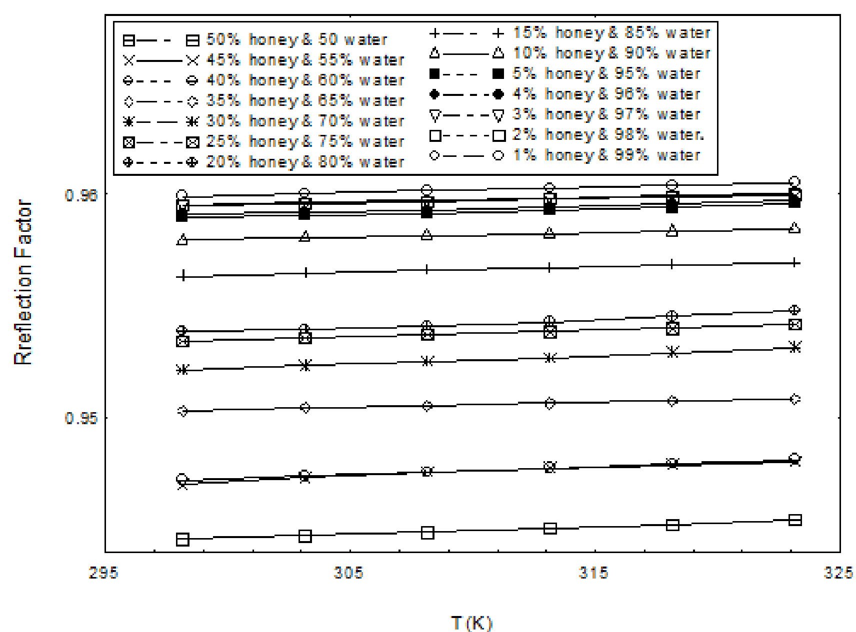


Figure (3.8.7): Reflection factormeasured versus temperature for different concentrations of aqueous honey solutions.

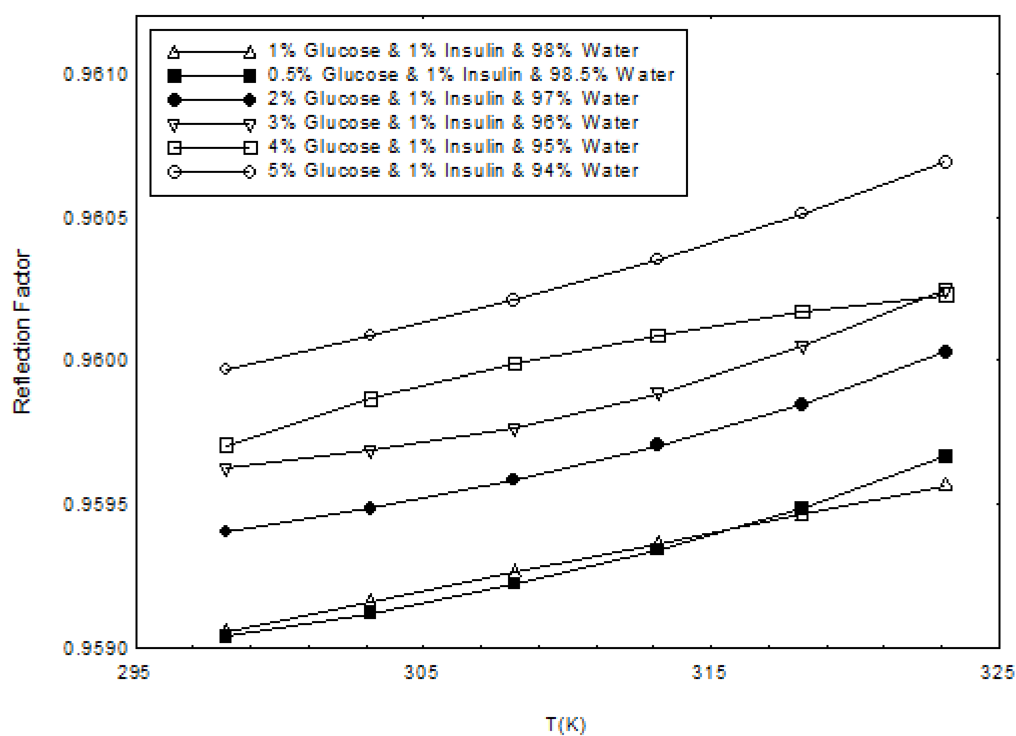


Figure (3.8.8): Reflection factormeasured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

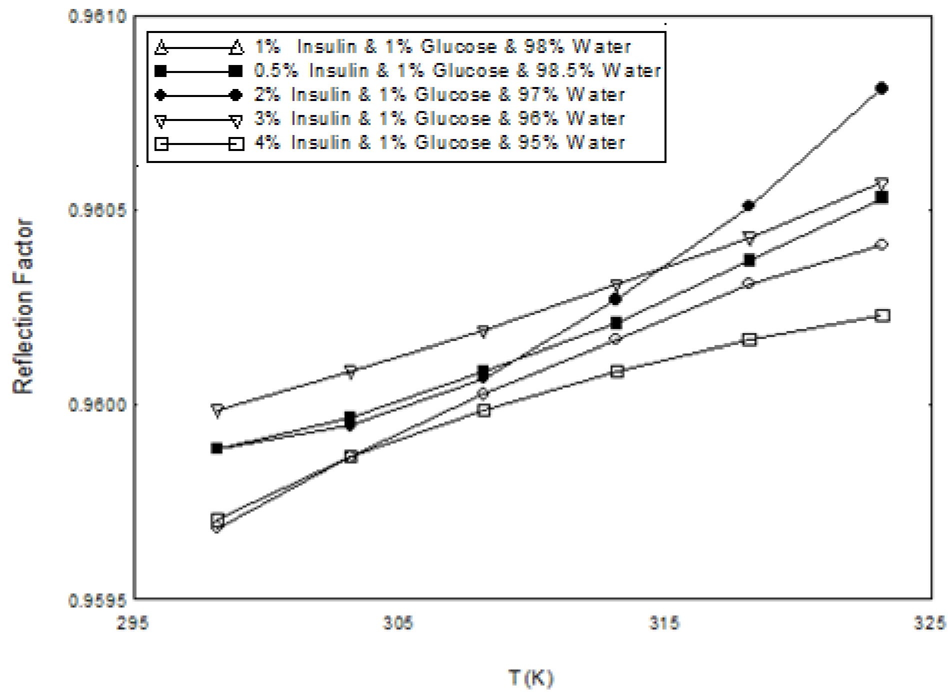


Figure (3.8.9): Reflection factormeasured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

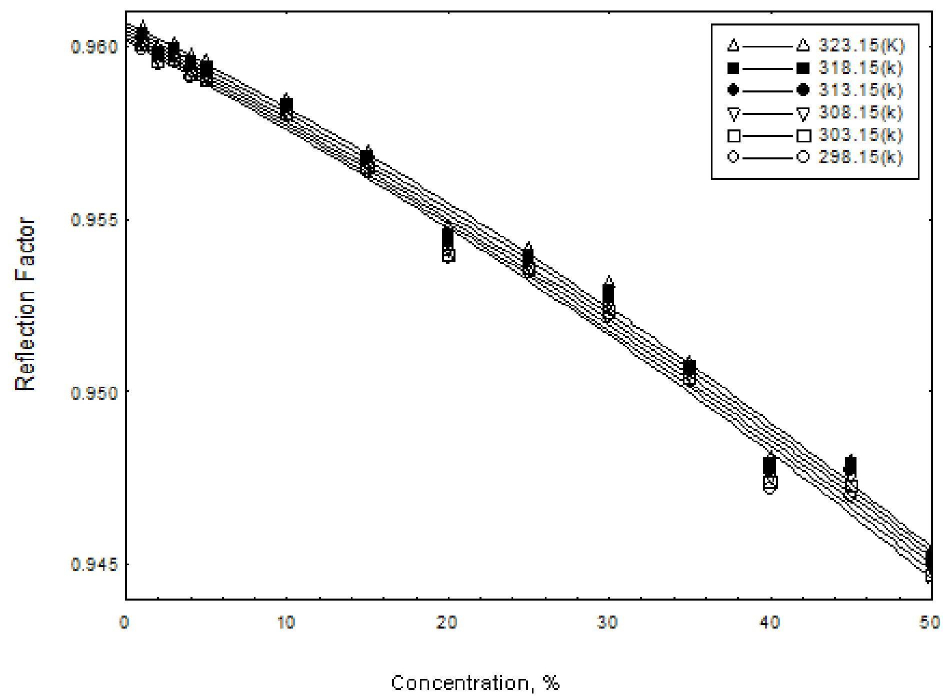


Figure (3.8.10): Reflection factormeasured versus concentration for different temperatures of aqueous honey solutions.

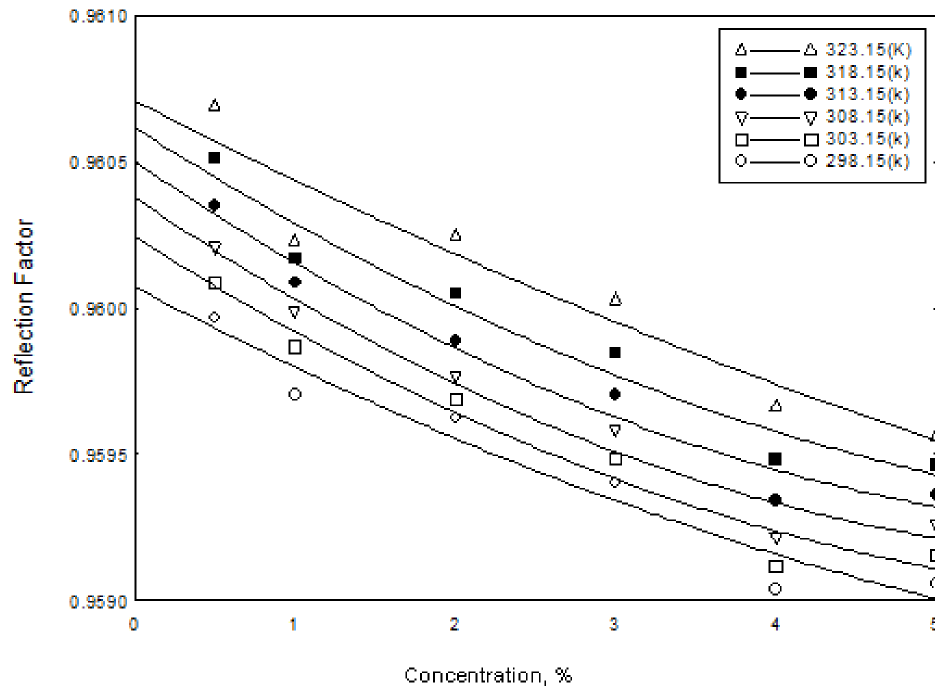


Figure (3.8.11): Reflection factormeasured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

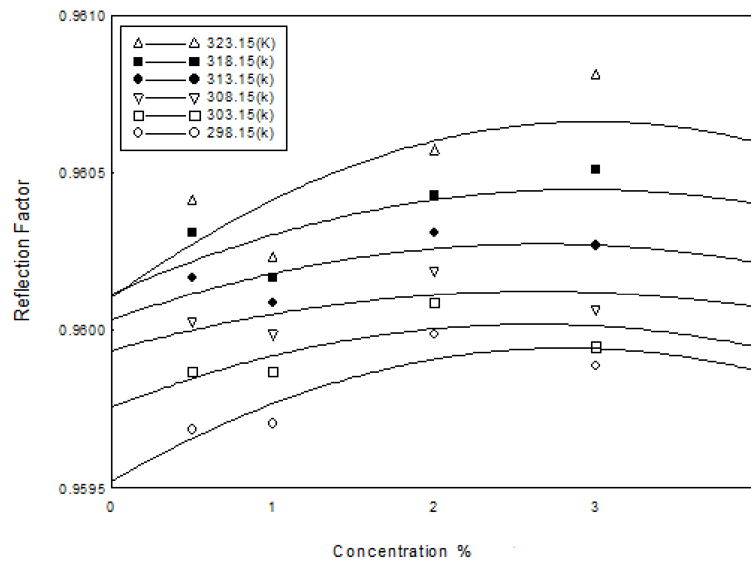


Figure (3.8.12): Reflection factormeasured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

From figures (3.8.7) and (3.8.10) it is noticed that the reflection factor slightly increases with increasing temperature but decreases with increasing honey concentration. The values of reflection factor for all temperatures and all honey concentrations of aqueous honey solutions are ranged from 0.944539 to 0.96051. Figures (3.8.8) and (3.8.11) show that the reflection factor decreased with increasing glucose concentration and increases with increasing temperature. The values of reflection factor for all temperatures and all glucose concentrations of aqueous glucose solutions mixed with one gram of insulin are ranged from 0.959055911 to 0.96069035. Figures (3.8.9) and (3.8.12) show that the reflection factor slightly increases with increasing insulin concentration and increases with increasing temperature. The values of reflection factor for all temperatures and all insulin concentrations of aqueous insulin solutions mixed with one gram of glucose are ranged from 0.959683788 to 0.960810632.

3.9. Thermal Gradient and Concentration Increment of Drag Coefficient of the Aqueous Honey Liquids and Aqueous Glucose/Insulin Mixtures

For the viscosity measurement of fluids in the falling sphere viscometer, it is necessary to find the viscosity drag of a ball falling slowly in an infinite medium of test fluid, which will be yield to the average shear stress acting on the surface of a sphere. This is related to the problem originally considered by Stokes, which was the slowly moving of Newtonian flow past of sphere. By completely neglecting the inertia effects in the flow field and by using a force balance equation on a sphere falling at a terminal velocity in viscous medium, Stokes obtained the following equation for the drag coefficient C_D:

$$C_D = 8R/[\rho_F u^2 \pi d^2] \cdots\cdots\cdots (3.9.1)$$

Where R is the viscosity resistance, ρ_F is the fluid density, u is the terminal velocity of the sphere and d is the sphere's diameter. The viscosity resistance R can be determined by:

$$R = \frac{\pi g d^3}{6}[\rho_S - \rho_F] \cdots\cdots\cdots (3.9.2)$$

Inserting equation (3.9.2) in equation (3.9.1) it is the found that drag coefficient as a function of sphere's velocity u (Kanchanalakshana and Ghajar, 1986): is equal to

$$C_D = \frac{4}{3}\frac{gd}{\rho_F u^2}[\rho_S - \rho_F] \cdots\cdots\cdots (3.9.3)$$

The diameter of the used sphere in viscometer is 15.66mm and the length of the falling sphere tube is 15cm. sphere velocity we can calculate the by measuring the time of falling sphere bein viscometer tube. Figures (3.9.1-6) show the calculated values of the sphere drag coefficient versus temperature and versus concentration respectively for samples of aqueous honey and aqueous glucose insulin solutions.

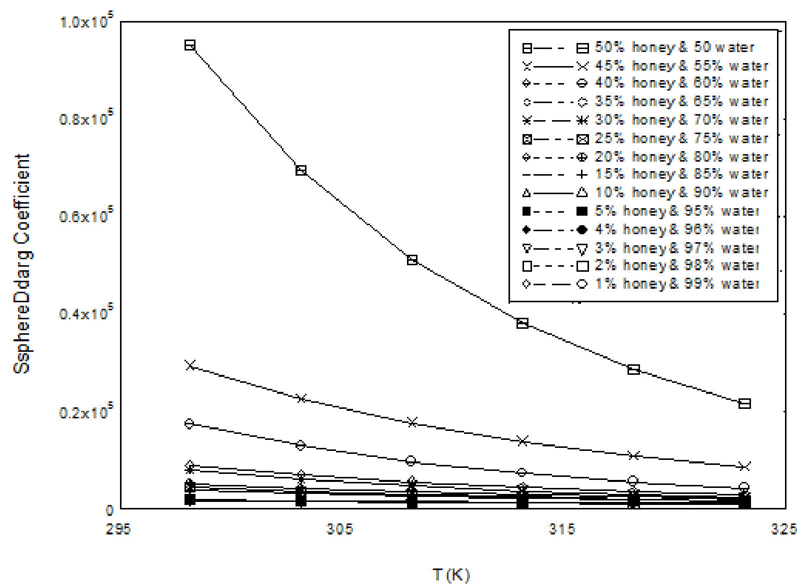


Figure (3.9.1): Sphere drag coefficient measured versus temperature for different concentrations of aqueous honey solutions.

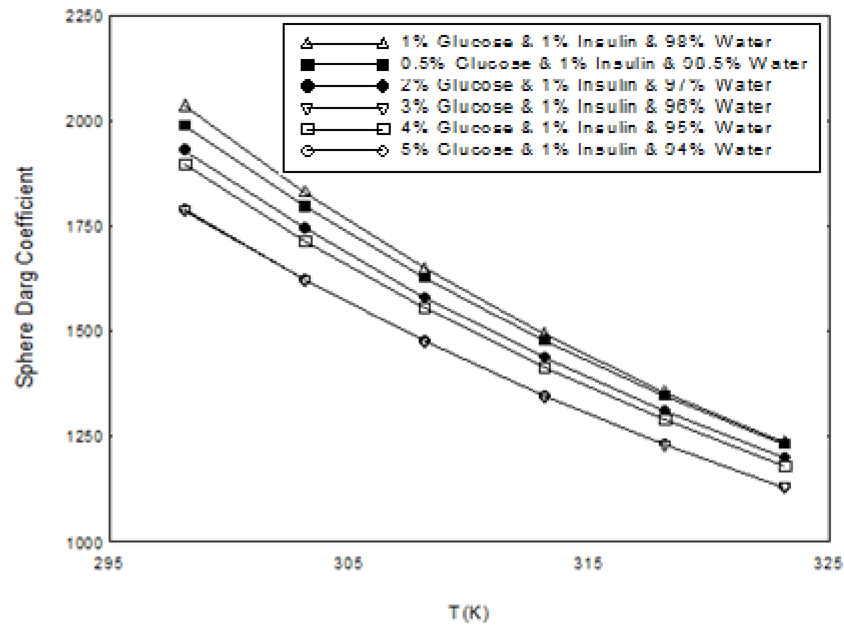


Figure (3.9.2): Sphere drag coefficient measured versus temperature for different concentrations of aqueous glucose solutions mixed with one gram of insulin.

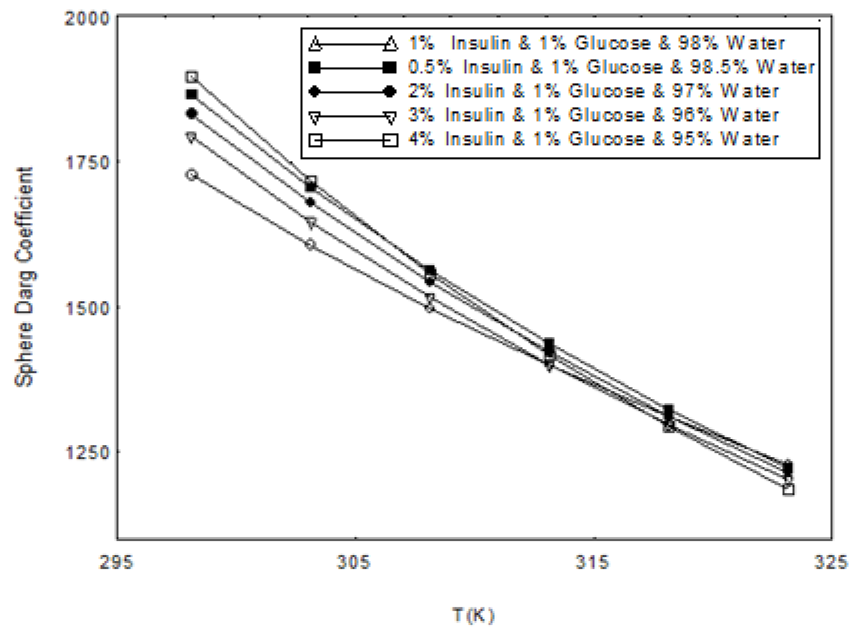


Figure (3.9.3): Sphere drag coefficient measured versus temperature for different concentrations of aqueous insulin solutions mixed with one gram of glucose.

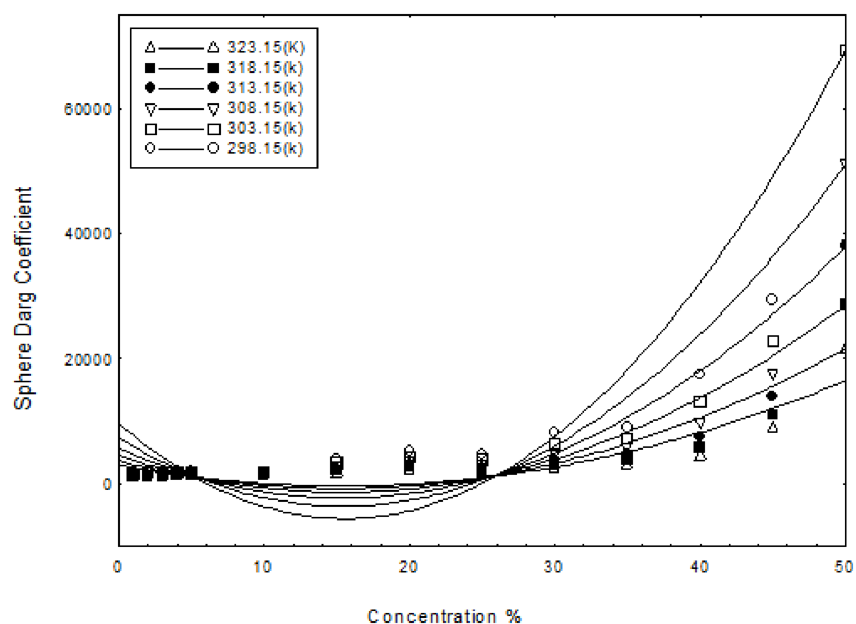


Figure (3.9.4): Sphere drag coefficient measured versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

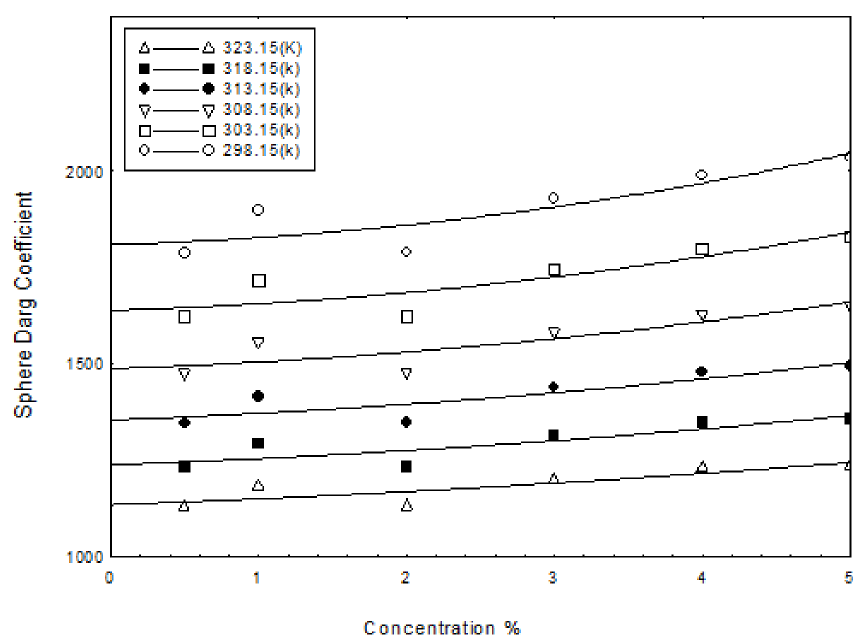


Figure (3.9.5): Sphere drag coefficient measured versus concentration for different temperatures of aqueous honey solutions.

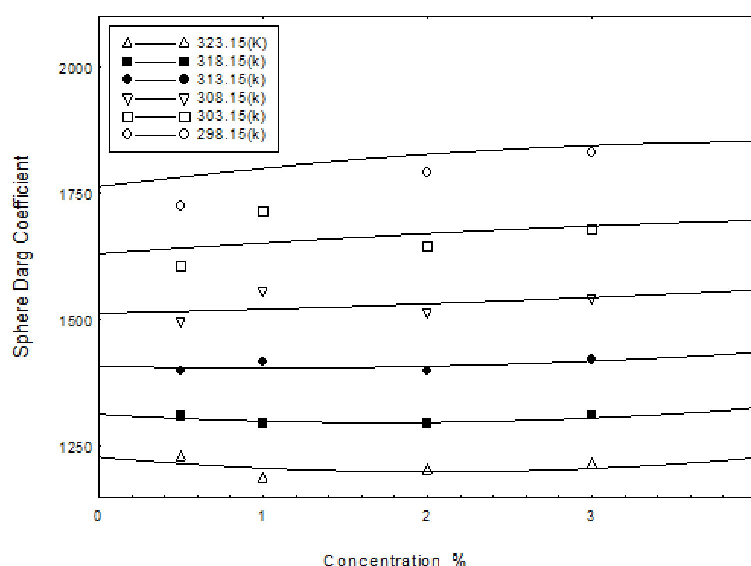


Figure (3.9.6): Sphere drag coefficient measured versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

From figures (3.9.1) and (3.9.4) it is noticed that the sphere's drag coefficient decreases with increasing temperature but increases with increasing honey concentration. The values of the sphere drag coefficient for all honey concentrations and for all temperatures are ranged from 1080.185 to 95265.87. Figures (3.9.2) and (3.9.5) show that the sphere drag coefficient increases with increasing glucose concentration but decreases with increasing temperature. The values of sphere drag coefficient for all temperatures and all glucose concentrations of aqueous glucose solutions mixed with one gram of insulin are ranged from 1129.25288 to 2033.670667. Figures (3.9.3) and (3.9.6) show that the sphere drag coefficient slightly increases with increasing insulin concentration are decreases with increasing temperature. The values of sphere drag coefficient for all temperatures and all insulin concentrations of aqueous insulin solutions mixed with one gram of glucose are ranged from 1186.074772 to 1865.085247.

The effect of temperature and concentration on thesphere drag coefficient could be accurately fitted by following polynomial equations:

$$C_D = A_{oC} + B_{oC}T + C_{oC}T^2 \cdots\cdots\cdots (3.9.4)$$

$$C_D = A_{oC} + B_{oC}C + C_{oC}C^2 \cdots\cdots\cdots (3.9.5)$$

The fitting constants A_{oC}, B_{oC}, and C_{oC} of the two previous equations are given in tables (3.9.1-6) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.9.1): The fitting constants of temperature polynomial model of sphere drag coefficient for all concentrations of aqueous honey solutions.

Concentration %	C_{oC} (k^{-2})	B_{oC} (k^{-1})	A_{oC}	R^2
1%	0.2275	-162.52	29942	1
2%	0.5040	-347.01	60586	0.9999
3%	0.3696	-258.06	45938	1
4%	0.4680	-324.45	57187	0.9999
5%	0.4090	-285.21	50682	1

Table (3.9.2): The fitting constants of temperature polynomial model of sphere drag coefficient for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration%	C_{oC} (k^{-2})	B_{oC} (k^{-1})	A_{oC}	R^2
0.5%	0.322	-226	4.06E+04	1
1%	0.361	-253	4.52E+04	1
2%	0.324	-227	4.08E+04	1
3%	0.369	-258	4.62E+04	1
4%	0.384	-269	4.80E+04	1
5%	0.417	-291	5.17E+04	1

Table (3.9.3): The fitting constants of temperature polynomial model of sphere drag coefficient for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	C_{oC} (k^{-2})	B_{oC} (k^{-1})	A_{oC}	R^2
0.5%	0.200	-1.44E+02	2.69E+04	1
1%	0.361	-2.52E+02	4.51E+04	1
2%	0.263	-1.87E+02	3.41E+04	1
3%	0.274	-1.95E+02	3.56E+04	1
4%	0.299	-2.12E+02	3.83E+04	1

Table (3.9.4): The fitting constants of concentration polynomial model of sphere drag coefficient for all temperatures of aqueous honey solutions.

T(K)	C_{oC}	B_{oC}	A_{oC}	R^2
298.15 (k)	630934	-195877	9499.9	0.7947
303.15 (k)	458120	-141521	7209.5	0.8018
308.15 (k)	336040	-103385	5571.4	0.8083
313.15 (k)	248903	-76351	4383.4	0.814
318.15 (k)	186103	-57002	3510	0.8188
323.15 (k)	140421	-43022	2859	0.8225

Table (3.9.5): The fitting constants of concentration polynomial model of sphere drag coefficient for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	C_{oC}	B_{oC}	A_{oC}	R
298.15	7.32E+04	1.07E+03	1.81E+03	0.771
303.15	5.80E+04	1.16E+03	1.64E+03	0.766
308.15	4.40E+04	1.26E+03	1.49E+03	0.756
313.15	3.21E+04	1.38E+03	1.35E+03	0.748
318.15	2.39E+04	1.36E+03	1.24E+03	0.738
323.15	1.55E+04	1.43E+03	1.13E+03	0.726

Table (3.9.6): The fitting constants of concentration polynomial model of sphere drag coefficient for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	C_{oC}	B_{oC}	A_{oC}	R^2
298.15 (k)	-2.92E+04	5.40E+03	1.70E+03	1
303.15 (k)	-3.49E+04	5.02E+03	1.56E+03	1
308.15 (k)	-3.67E+04	4.52E+03	1.44E+03	1
313.15 (k)	-3.47E+04	3.90E+03	1.34E+03	1
318.15 (k)	-2.94E+04	3.16E+03	1.24E+03	1
323.15 (k)	-2.15E+04	2.33E+03	1.16E+03	1

The derivative to temperature of the temperature polynomial equation (3.9.4) and the derivativeto concentration of the concentration polynomial equation (3.9.5) give the following thermal gradient dC_D/dT and concentration increment dC_D/dC of sphere drag coefficient:

$$\frac{dC_D}{dT} = A_C + B_C T + C_C T^2 \cdots\cdots\cdots (3.9.6)$$

$$\frac{dC_D}{dC} = A_C + B_C C + C_C C^2 \cdots\cdots\cdots (3.9.7)$$

The fitting constants A_C, B_C, and C_C of the two previous equations are given in tables (3.9.7-12) for all samples of aqueous honey and aqueous glucose insulin solutions.

Table (3.9.7): The fitting constants of temperature polynomial model of temperature gradient of sphere drag coefficient for all concentrations of aqueous honey solutions.

Concentration %	A_C (k^{-1})	B_C (k^{-2})	C_C	R^2
1%	-162.52	0.455	0	1
2%	-347.01	1.008	0	1
3%	-258.06	0.739	0	1
4%	-324.45	0.936	0	1
5%	-285.21	0.818	0	1

Table (3.9.8): The fitting constants of temperature polynomial model of temperature gradient of sphere drag coefficient for all concentrations of aqueous glucose solutions mixed with one gram of insulin.

Concentration %	A_C (k^{-1})	B_C (k^{-2})	C_C	R^2
0.5%	-226	0.644	0	1
1%	-253	0.722	0	1
2%	-227	0.648	0	1
3%	-258	0.738	0	1
4%	-269	0.768	0	1
5%	-291	0.834	0	1

Table (3.9.9): The fitting constants of temperature polynomial model of temperature gradient of sphere drag coefficient for all concentrations of aqueous insulin solutions mixed with one gram of glucose.

Concentration %	A_C (k^{-1})	B_C (k^{-2})	C_C	R^2
0.5%	-144	0.400	0	1
1%	-252	0.722	0	1
2%	-187	0.526	0	1
3%	-195	0.548	0	1
4%	-212	0.598	0	1

Table (3.9.10): The fitting constants of concentration polynomial model of sphere drag coefficient for all temperatures of aqueous honey solutions.

T(K)	A_C	B_C	C_C	R^2
298.15 (k)	-195877	1.26E+06	0	1
303.15 (k)	-141521	9.16E+05	0	1
308.15 (k)	-103385	6.72E+05	0	1
313.15 (k)	-76351	4.98E+05	0	1
318.15 (k)	-57002	3.72E+05	0	1
323.15 (k)	-43022	2.81E+05	0	1

Table (3.9.11): The fitting constants of concentration polynomial model of sphere drag coefficient for all temperatures of aqueous glucose solutions mixed with one gram of insulin.

T(K)	A_C	B_C	C_C	R^2
298.15 (k)	1.07E+03	1.46E+05	0	1
303.15 (k)	1.16E+03	1.16E+05	0	1
308.15 (k)	1.26E+03	8.80E+04	0	1
313.15 (k)	1.38E+03	6.42E+04	0	1
318.15 (k)	1.36E+03	4.78E+04	0	1
323.15 (k)	1.43E+03	3.10E+04	0	1

Table (3.9.12): The fitting constants of concentration polynomial model of sphere drag coefficient for all temperatures of aqueous insulin solutions mixed with one gram of glucose.

T(K)	A_C	B_C	C_C	R^2
298.15 (k)	5.40E+03	-5.84E+04	0	1
303.15 (k)	5.02E+03	-6.98E+04	0	1
308.15 (k)	4.52E+03	-7.34E+04	0	1
313.15 (k)	3.90E+03	-6.94E+04	0	1
318.15 (k)	3.16E+03	-5.88E+04	0	1
323.15 (k)	2.33E+03	-4.30E+04	0	1

3.10. Thermal Expansion Coefficient of the Aqueous Honey Solutions

Thermal expansion is the tendency of a matter to change in volume in response with change in temperature, through heat transfer. Temperature

is a monotonic function of the average molecular kinetic energy of a substance. When a substance is heated, the kinetic energy of its molecules increases. Thus, the molecules begin moving more and usually maintain a greater average separation. The degree of expansion is divided by the change in temperature is called the material coefficient of thermal expansion γ_v and generally varies with temperature. Thermal expansion can be determined at constant pressure using the following equation:

$$\gamma_v = \frac{1}{V}\frac{dV}{dT} = -\frac{1}{\rho}\frac{d\rho}{dT} \quad \cdots\cdots\cdots (3.10.1)$$

Where V is the liquid volume and ρ is the liquid density. In recent study thermal gradient of density is used the dρ/dT (given in table 3.2.4) to calculate the thermal expansion of aqueous honey samples. Figures (3.10.1) and (3.10.2) show the calculated thermal expansion coefficient of aqueous honey solutions versus temperature and versus concentration respectively.

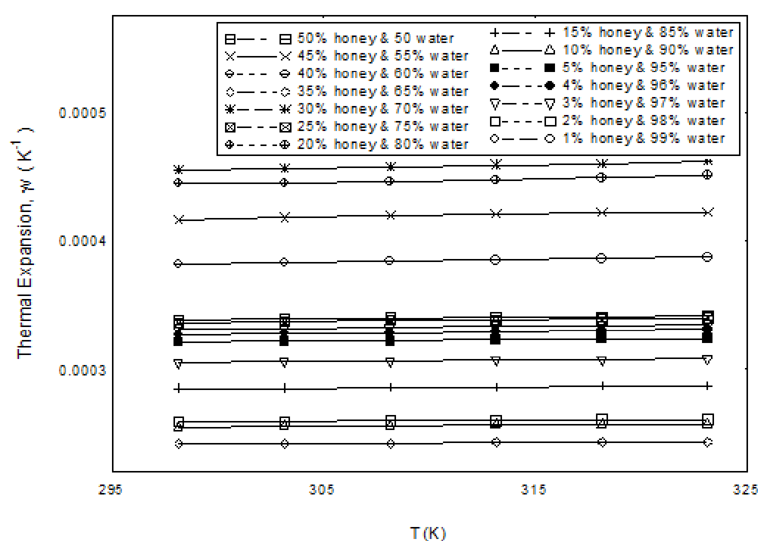


Figure (3.10.1): Thermal Expansionmeasured versus temperature for different concentrations of aqueous honey solutions.

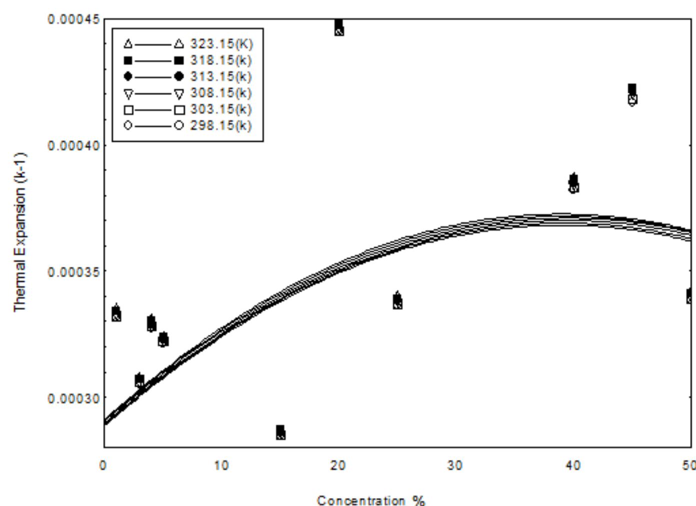


Figure (3.10.2): Thermal Expansion measured versus concentration for different temperatures of aqueous honey solutions.

From figures (3.10.1) and (3.10.2) it is noticed that the thermal expansion calculated values independent of temperature but varies on honey concentration. The values of thermal expansion of all aqueous honey samples are ranged from $0.00024K^{-1}$ to $0.00046K^{-1}$. The effect of temperature and concentration on thermal expansion coefficient could be accurately fitted by following polynomial equations:

$$\gamma_v = A_{o\gamma} + B_{o\gamma}T + C_{o\gamma}T^2 \cdots\cdots\cdots (3.10.2)$$

$$\gamma_v = A_{o\gamma} + B_{o\gamma}C + C_{o\gamma}C^2 \cdots\cdots\cdots (3.10.3)$$

The fitting constants $A_{o\gamma}$, $B_{o\gamma}$, and $C_{o\gamma}$ of the two previous equations are given in tables (3.10.1) and (3.10.2) for all samples of aqueous honey solutions.

Table (3.10.1): The fitting constants of temperature polynomial model of thermal expansion for all concentrations of aqueous honey solutions.

Concentration %	$C_{o\gamma}$ (k^{-3})	$B_{o\gamma}$ (k^{-2})	$A_{o\gamma}$ (k^{-1})	R^2
1%	7.00E-10	3.00E-07	0.0004	0.9445
2%	3.00E-21	9.00E-08	0.0002	0.9143
3%	3.00E-21	1.00E-07	0.0003	0.9377
4%	3.00E-09	-2.00E-06	0.0006	0.9789
5%	-7.00E-10	6.00E-07	0.0002	0.9445

Table (3.10.2): The fitting constants of concentration polynomial model of thermal expansion for all temperatures of aqueous honey solutions.

T(K)	$C_{o\gamma}$ (k^{-1})	$B_{o\gamma}$ (k^{-1})	$A_{o\gamma}$ (k^{-1})	R^2
298.15 (k)	-5.19E-04	4.07E-04	2.89E-04	1.95E-01
303.15 (k)	-5.21E-04	4.07E-04	2.89E-04	1.95E-01
308.15 (k)	-5.17E-04	4.07E-04	2.90E-04	1.97E-01
313.15 (k)	-5.16E-04	4.08E-04	2.90E-04	1.96E-01
318.15 (k)	-5.29E-04	4.14E-04	2.91E-04	1.96E-01
323.15 (k)	-5.36E-04	4.18E-04	2.91E-04	1.95E-01

3.11. The Thermal and Concentration Equations of Dynamic Viscosity of the Aqueous Honey and Aqueous Glucose/Insulin Solutions Using Semi Empirical Models of Mixing Rules

Several semi-empirical models have been used to calculate the dynamic viscosities of mixtures theoretically in terms of pure component data. The following semi empirical models have been tested for the solutions under study:

Reynolds model equation:

$$\eta = Be^{\alpha T} \cdots\cdots\cdots\cdots (3.11.1)$$

Grunberg and Nissan model equation (Ali *et al.*, 2006; Yadava*et al.*, 2010):

$$ln\eta = x_1 ln\eta_1 + x_2 ln\eta_2 + x_1 x_2 G_{12} \cdots\cdots\cdots\cdots (3.11.2)$$

Hind, McLaughlin and Ubbelohde model equation (Ali *et al.*, 2006):

$$\eta = x_1^2\eta_1 + x_2^2\eta_2 + 2x_1x_2H_{12} \cdots\cdots\cdots (3.11.3)$$

Where (B, α) are the adjustable parameters of Reynolds equation, (x_1, x_2) are the mole fractions of the first and second pure component, (η_1, η_2) are the dynamic viscosity of the first and second pure component, (G_{12}, H_{12}) are the interaction parameters of Grunberg and Nissan equation and Hind, McLaughlin and Ubbelohde equation and η is the dynamic viscosity of mixture. The interaction parameter $G_{12}$of Grunberg and Nissan equation is proportional to W/RT, W being the interaction energy. G_{12}may be regarded as an approximate measure of the strength of interaction between the components (Yadara *et al.*, 2010).

Figures (3.11.1-6) show the Reynolds model B and α parameters versus concentration for all aqueous honey and aqueous glucose insulin solutions. Figures (3.11.7-10) illustrate the interaction parameters of Grunberg and Nissan equation G_{12} and Hind, McLaughlin and Ubbelohde equation H_{12} versus concentration for all temperatures of aqueous honey and aqueous glucose insulin solutions.

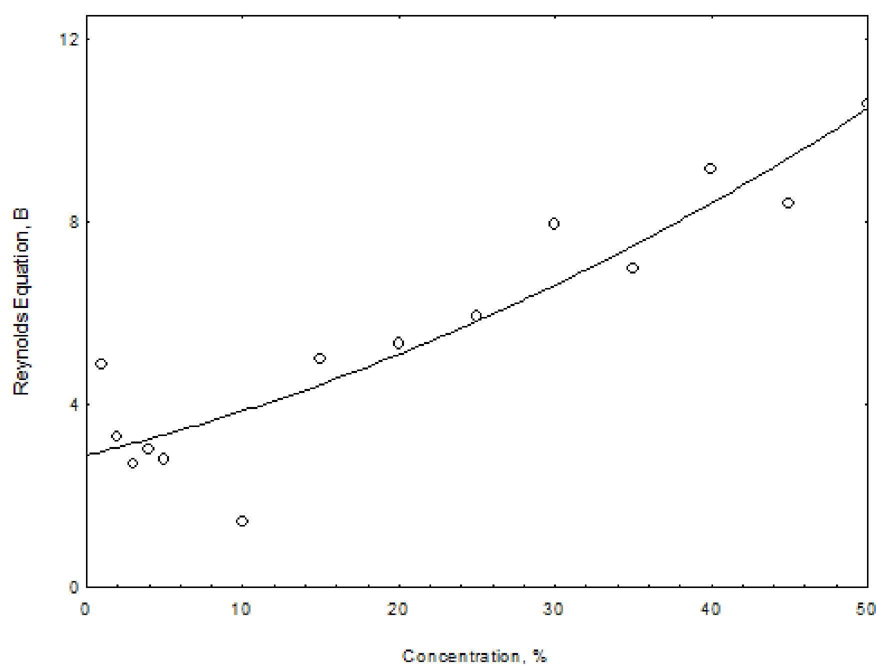


Figure (3.11.1): Reynolds model Bversus concentration for different temperatures of aqueous honey solutions..

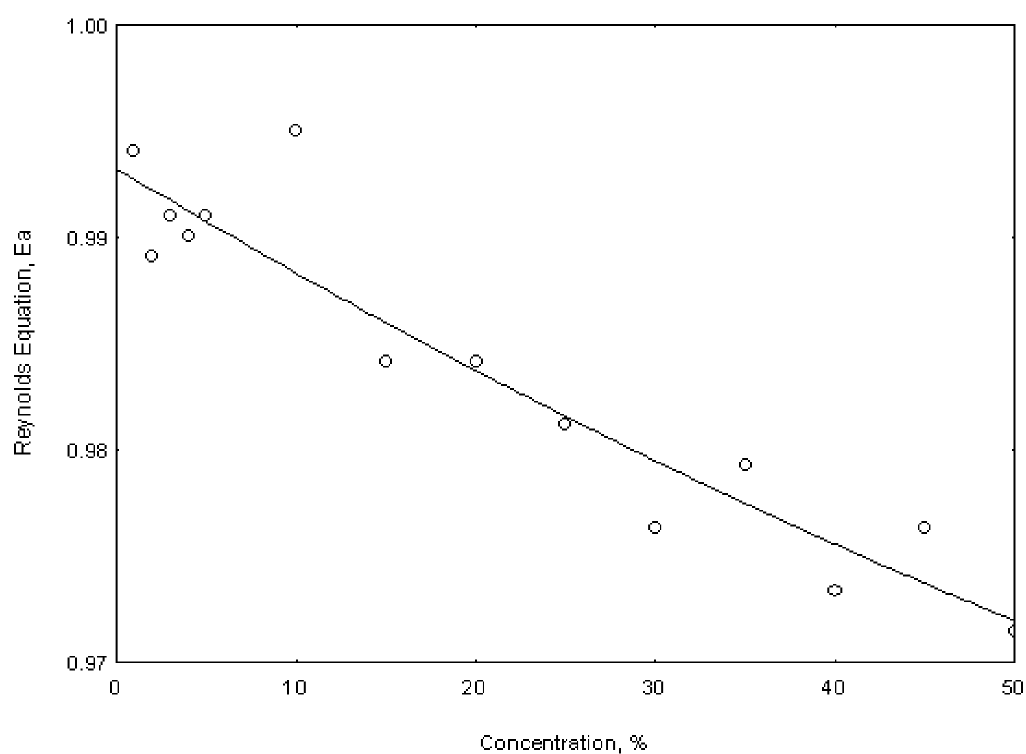


Figure (3.11.2): Reynolds model αversus concentration for different temperatures of aqueous honey solutions.

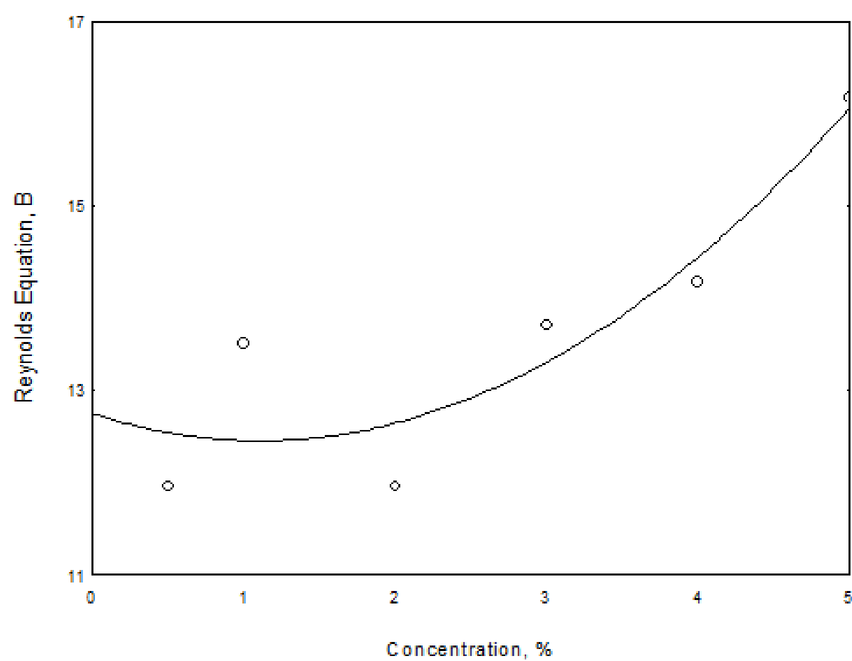


Figure (3.11.3): Reynolds model Bversus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

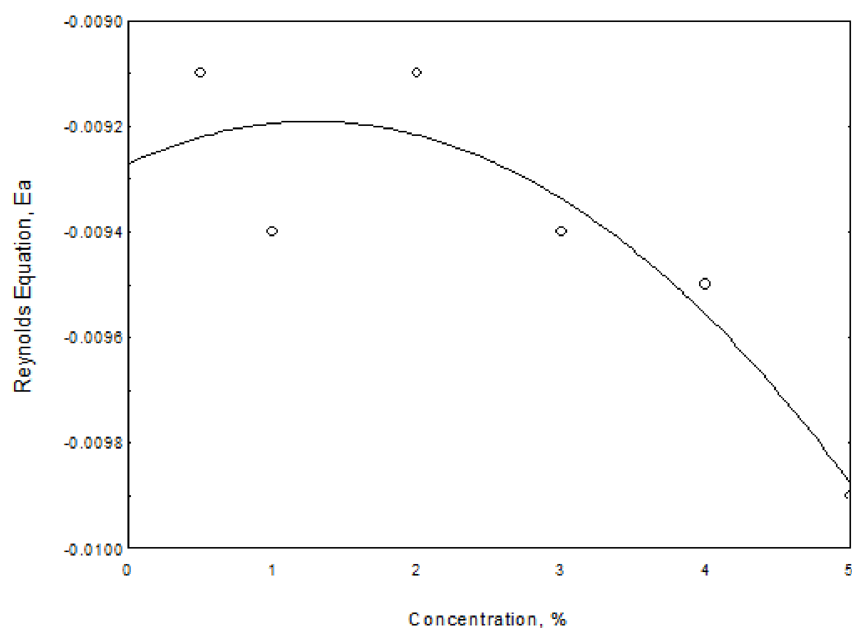


Figure (3.11.4): Reynolds model α versus concentration for different temperatures of aqueous glucose solutions mixed with one gram of insulin.

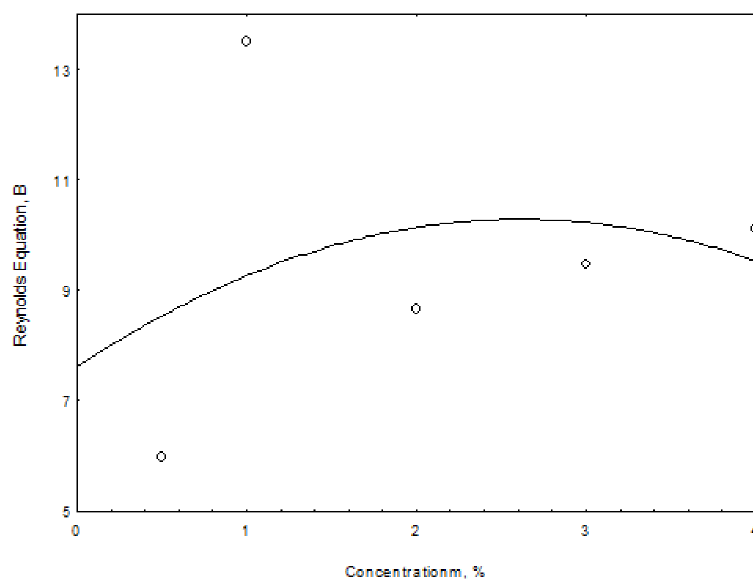


Figure (3.11.5): Reynolds model Bversus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

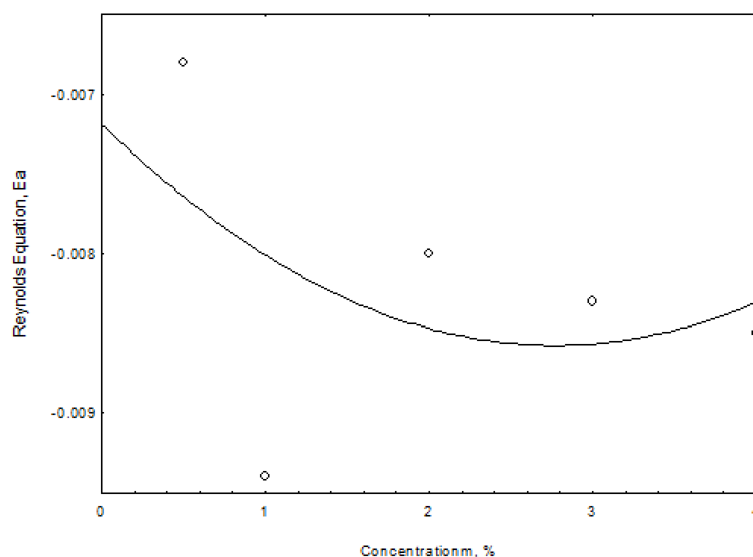


Figure (3.11.6): Reynolds model α versus concentration for different temperatures of aqueous insulin solutions mixed with one gram of glucose.

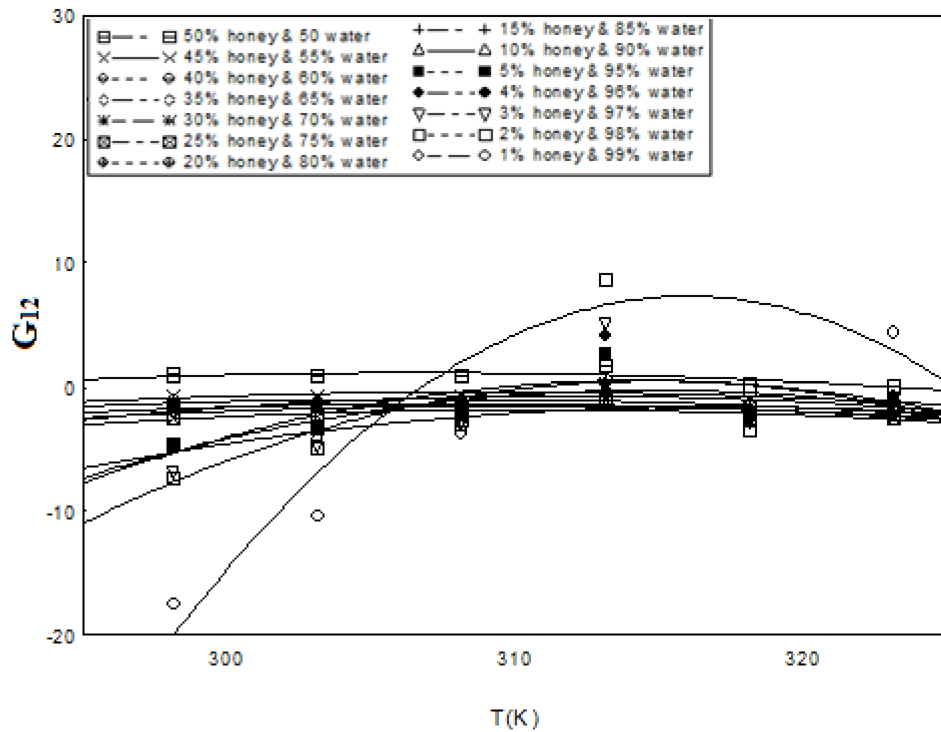


Figure (3.11.7): Illustrate the interaction parameters of Grunberg and Nissan equation G_{12}measured versus temperature for different concentrations of aqueous honey solutions.

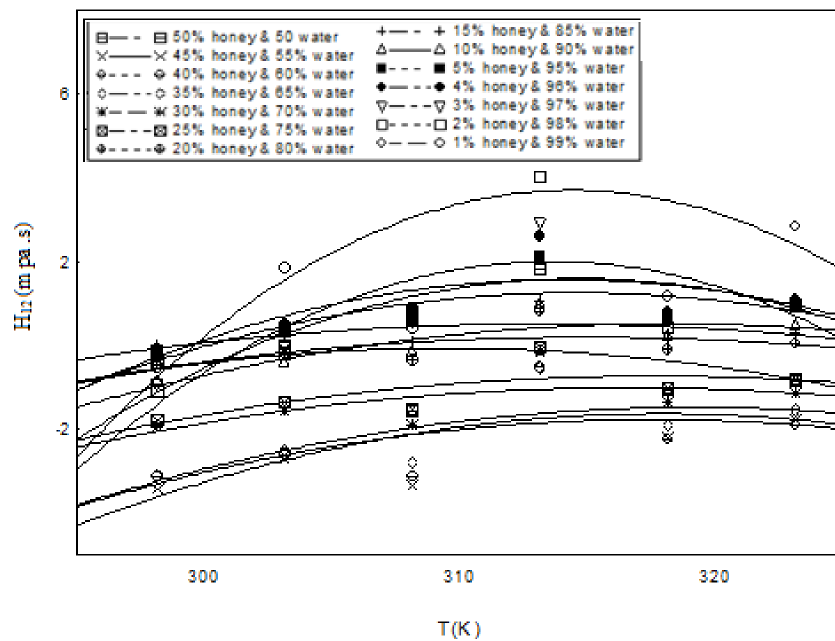


Figure (3.11.8): Illustrate the interaction parameters of Hind, McLaughlin and Ubbelohd equation H_{12}measured versus temperature for different concentrations of aqueous honey solutions.

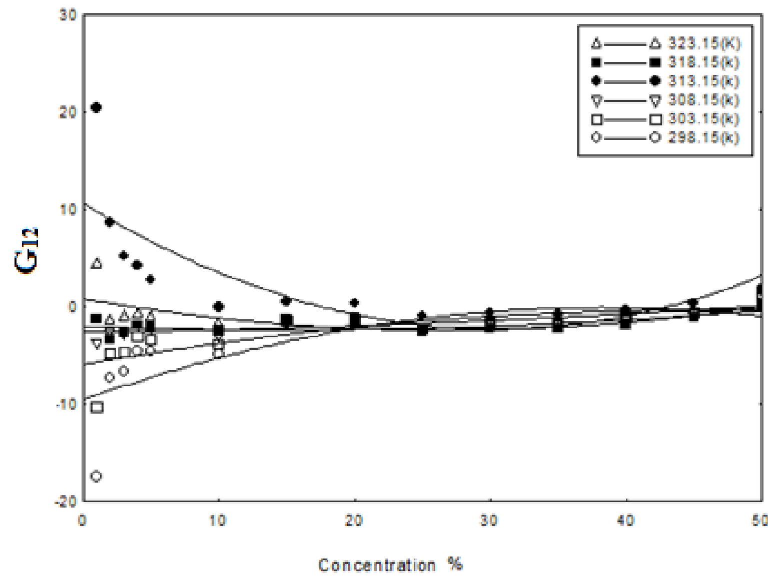


Figure (3.11.9): Illustrate the interaction parameters of Grunberg and Nissan equation G_{12}measured versus concentration for different temperatures of aqueous honey solutions.

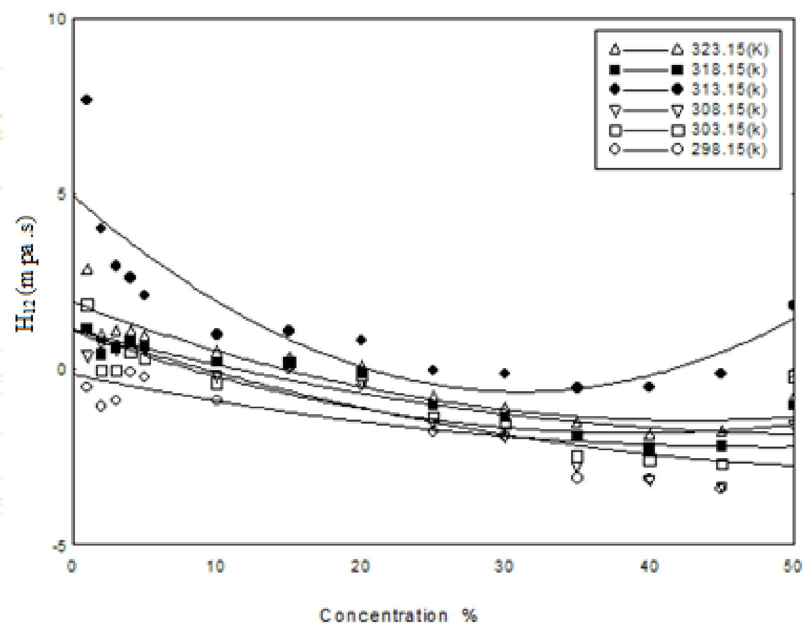


Figure (3.11.10): Illustrate the interaction parameters of Hind, McLaughlin and Ubbelohd equation H_{12}measured versus concentration for different temperatures of aqueous honey solutions.

3.12. Dry Matter, Ash Content, Moisture Content, Water Activity and pH of the Aqueous Honey Liquids

The dry matter (or other word known as dry weight) measurementis the mass of something when is completely dried. The dry matter of plant and animal material would be its solids, i.e. all its constituents excluding water. The dry matter of food would include carbohydrates, fats, proteins, vitamins, mineral, and antioxidants (e.g., thiocyanate, anthocyanin, and quercetin). Ash content, expressed as the percentage of residue left after dry oxidation by weight (g/100 g honey). Honey normally has low ash content and it depends on the materialcollected by the bees during foraging on the flora(Nigussie*et al.*, 2012).Moisture content or water content is the quantity of water contained in a material, such as soil (called soil moisture), rock, ceramics, fruit, or wood. Water content is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis. Water activity or a_w is the partial vapor pressure of water in a substance divided by the standard state partial vapor pressure of water. In the field of food science, the standard state is most often defined as the partial vapor pressure of pure water at the same temperature. Using this particular definition, pure distilled water has a water activity of exactly one. As temperature increases, a_w typically increases except in some products with crystalline salt or sugar. Higher a_w substances tend to support more microorganisms. Bacteria usually require at least 0.91, and fungi at least 0.7. Water migrates from areas of high a_w to areas of low a_w. For example, if honey ($a_w \approx 0.6$) is exposed to humid air ($a_w \approx 0.7$), the honey absorbs water from the air. If salami ($a_w \approx 0.87$) is exposed to dry air ($a_w \approx 0.5$), the salami dries out, which could preserve it or spoil it. In chemistry, pH is a measure of the acidity or alkalinity of

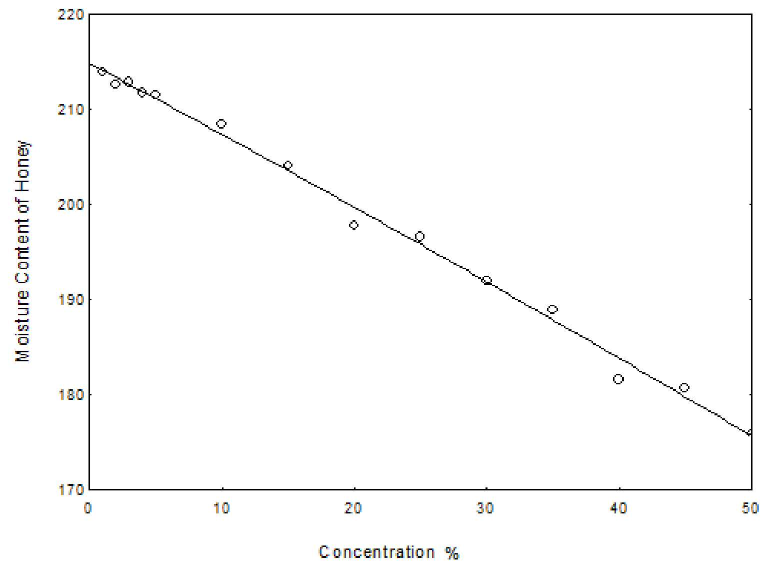
an aqueous solution. The pH at neutrality is designated as 7.0. When H^+ ions exceed OH^- ions in number, the reaction is acidic. The pH values in this case fall below 7.0. They range from just under 7.0 all the way down to 0, depending on the relative strength of the reaction. The stronger the reaction causes the lower pH value. When OH^- ions exceed H^+ ions in number, the reaction is considered to be alkaline (or basic). The pH values of alkaline reactions are ranged from just over 7.0 up to 14.0, depending upon the degree of alkalinity. The more alkaline reaction causes the higher pH value. In mathematical terms, pH is designated as follows:

$$\frac{1}{pH} = log[H^+] or pH = -log[H^+] \cdots\cdots\cdots\cdots (3.12.1)$$

Because a log scale is involved, each unit change in pH reflects a 10 fold change in acidity or alkalinity.

Moisture content versus honey concentration shown in figure (3.12.1) was determined by the measured refractive index coefficient at 20 ^oC using the following the empirical relation (Belie, 2009 and Adams *et al.* ,2010).

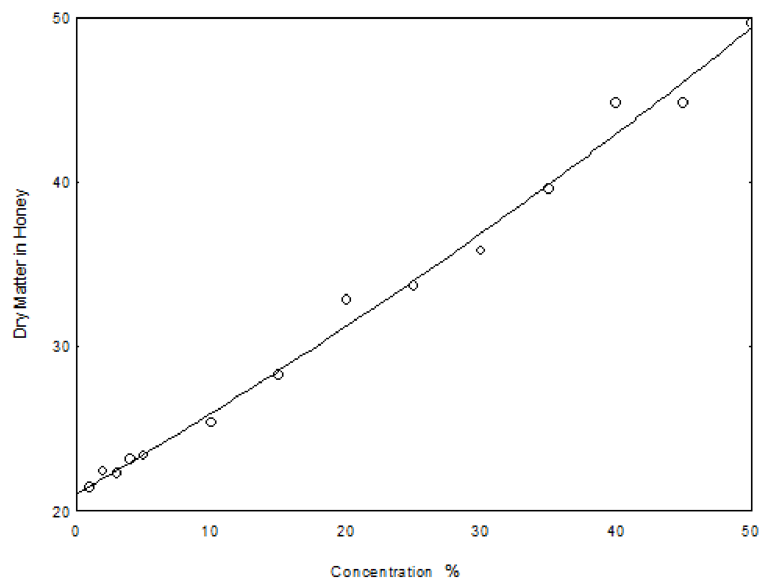
$$w = \frac{[1.7319 - \log(n_{20} - 1]}{0.002243} \cdots\cdots\cdots\cdots (3.12.2)$$



Figures (3.12.1):Moisture content versus honey concentration for aqueous honey solutions

Dry matter content versus honey concentration shown in figure (3.12.2) was calculated by the measured refractive index coefficients using the imperial relation (white, 1975)

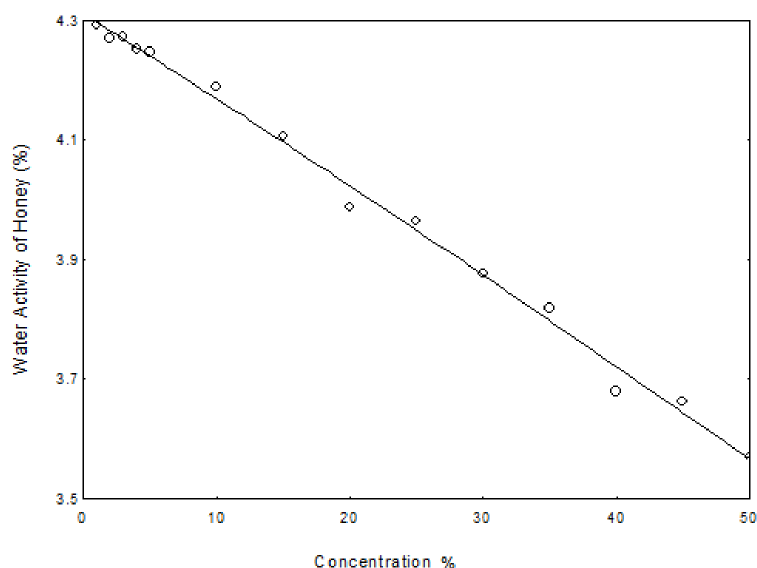
$$Dry\ matter = 78 + 390.7(n_{40} + 1.4768) \cdots\cdots\cdots (3.12.3)$$



Figures (3.12.2): Dry matterversus honey concentration for aqueous honey solutions.

Water activity honey concentration shown in figures (3.12.3) was defined by calculation values of moisture content using the empirical relation (Abramoric *et al*., 2008.

a_w = 0.23 + 0.019 w·········· (3.12.4)



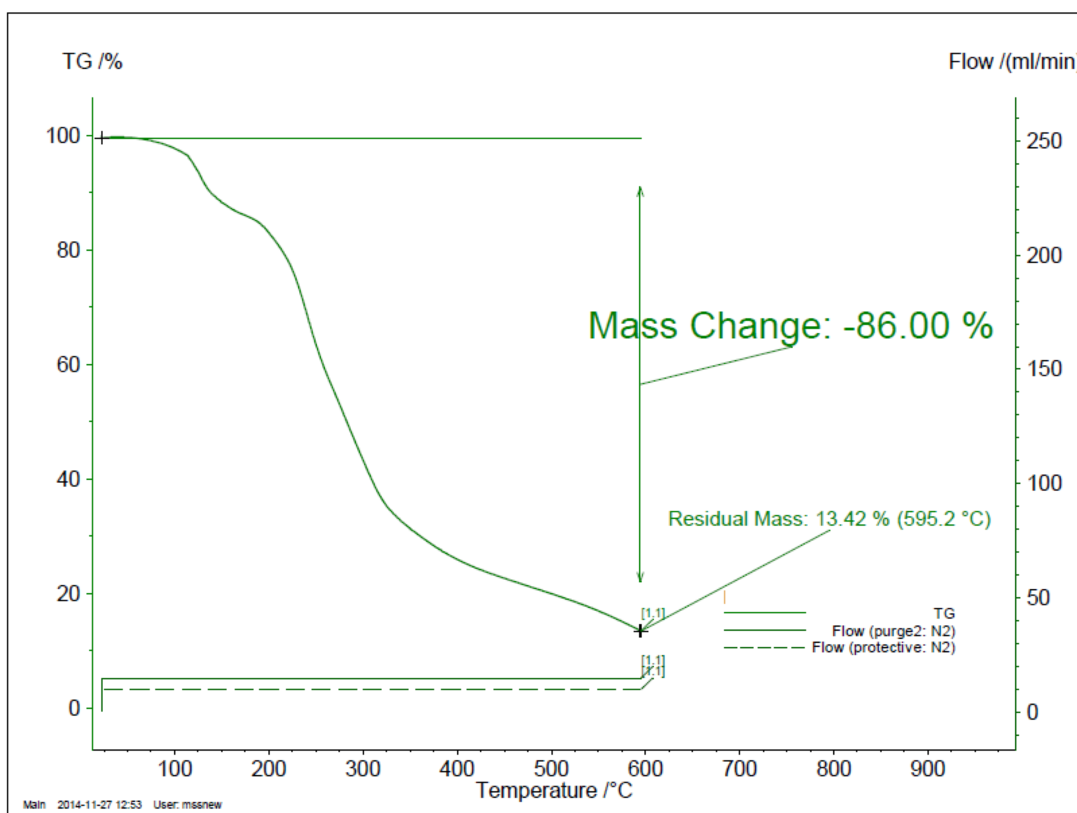
Figures (3.12.3): water activity versus honey concentration for aqueous honey solutions.

Figures (3.12.1), (3.12.2) and (3.12.3) show the dry matter, moisture content and water activity versus honey concentration for aqueous honey solutions. From previous figures (3.12.1), (3.12.2) and (3.12.3) it is noticed that the moisture content and water activity linearly decreases with increasing honey concentration but dry matter increases with increasing honey concentration. Table (3.12.1) give moisture content and Ash content for pure honey sample.

Table (3.12.1): The measured values of pH, dry content and ash content.

pH	4.31-4.2
Ash content	44.1%
Dry matter	85%

Figure (3.12.4) shows the change of pure honey mass with increasing heat temperature using thermogravimetric method.



Figures (3.12.4): Thermogravimetric curve of pure honey sample.

3.13. Optical Absorption and XRF spectrometry of Aqueous Honey Liquids and Insulin

The absorption coefficient α is defined as the ability of a material to absorb the light of a given wavelength λ and it can be expressed by Lambert Beer's law (Hamad, 2013):

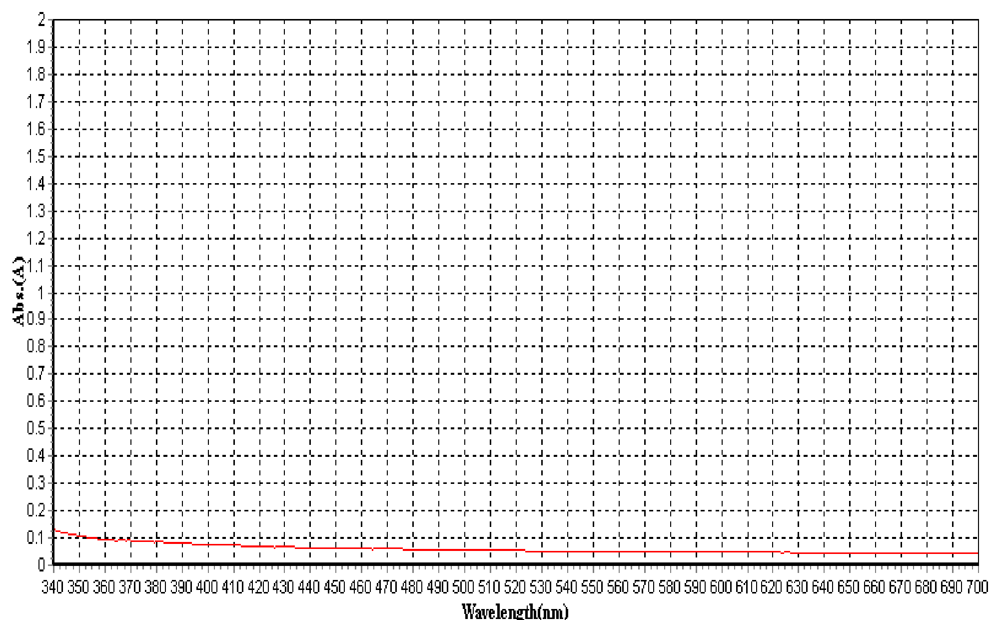
$$\propto = 2.3[A/x] \cdots\cdots\cdots (3.13.1)$$

Where, x is the sample thickness and A is the absorbance measured by the spectrophotometer. The absorbance A is defined as the logarithm of the ratio between absorbed light intensity I by the material and the incident intensity of light I_o (Hamad, 2013):

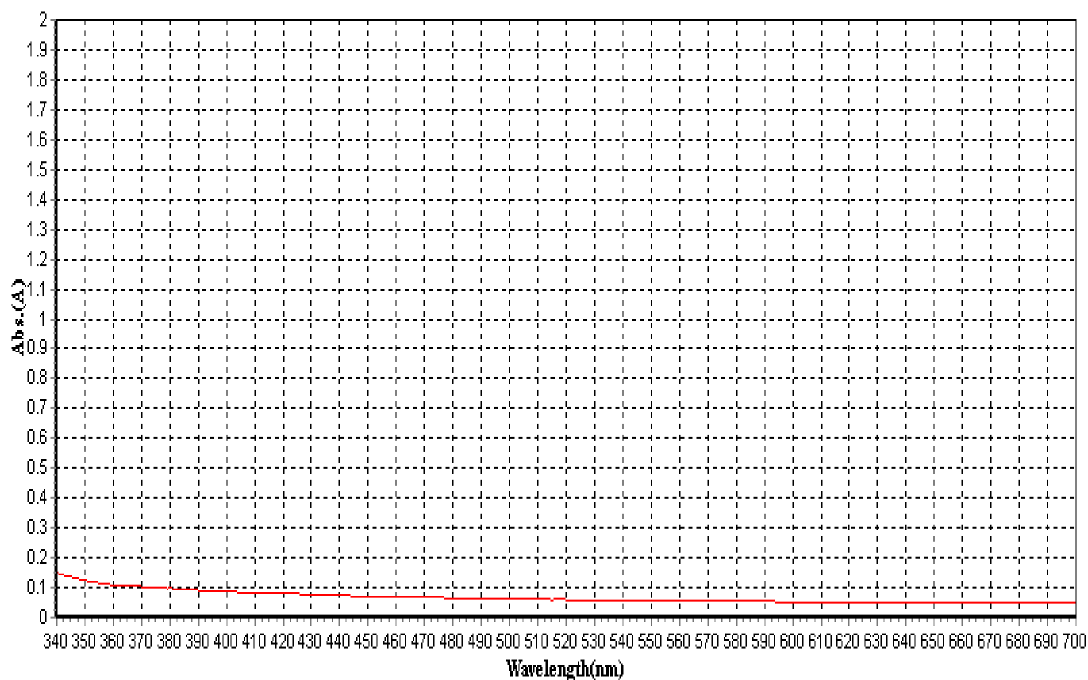
$$A = -\log T = \log\left[\frac{I_o}{I}\right] \cdots\cdots\cdots (3.13.2)$$

Where T is the spectral transmittance of the material. McNichols (2000) reported the optical activity and the optical absorption for a wide spectral range of aqueous glucose solution. Figures (3.13.1-15) show the

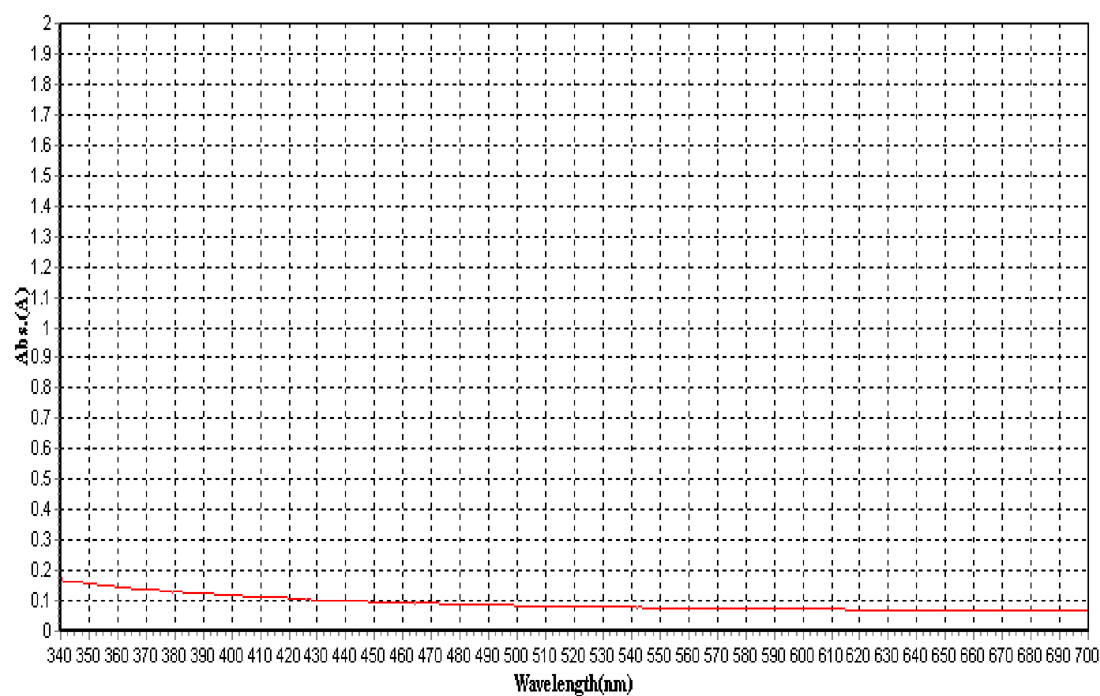
measured optical absorption coefficients of aqueous honey solutions and pure insulin liquid at room temperature.



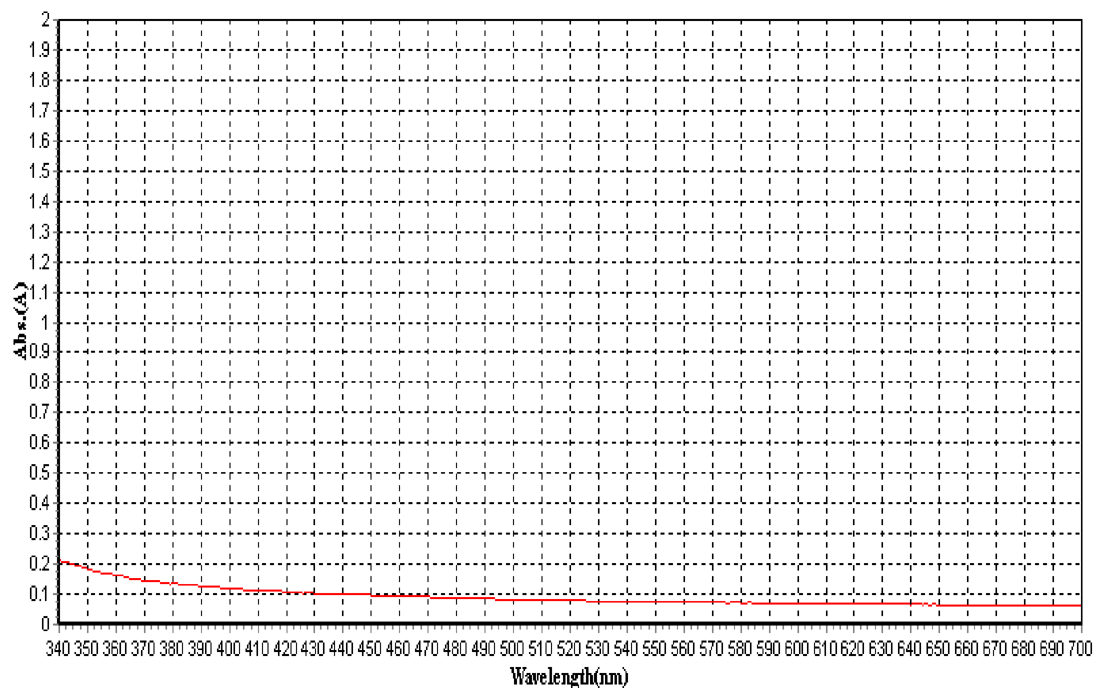
Figures (3.13.1):Optical absorption coefficients of aqueous honey (1%) versuswavelength.



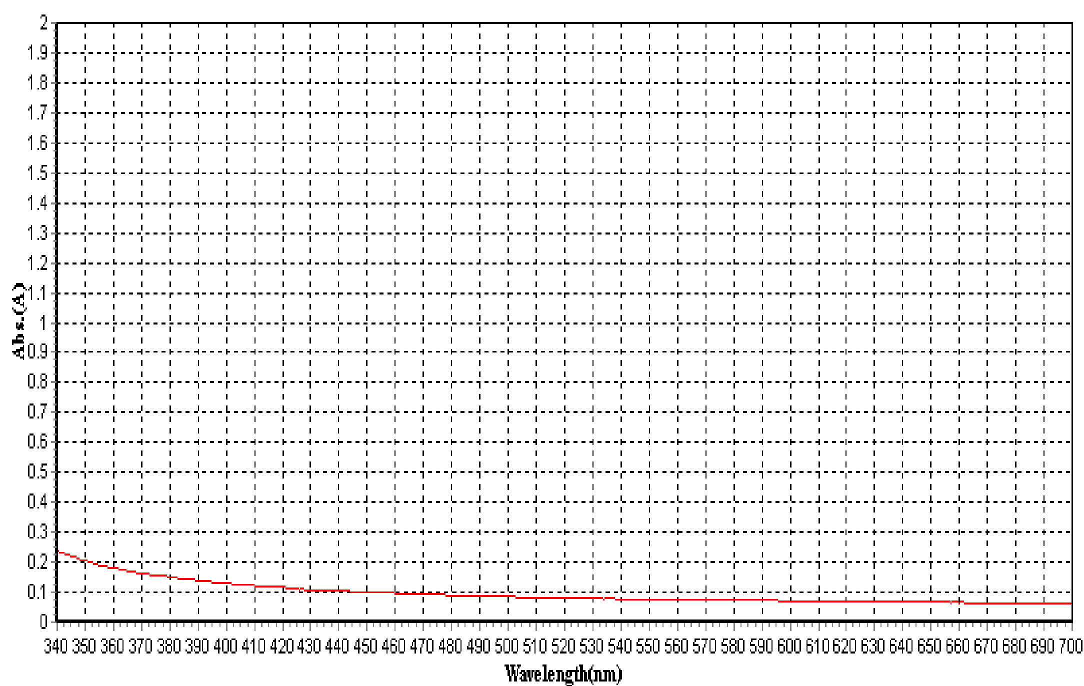
Figures (3.13.2): Optical absorption coefficients of aqueous honey (2%) versuswavelength.



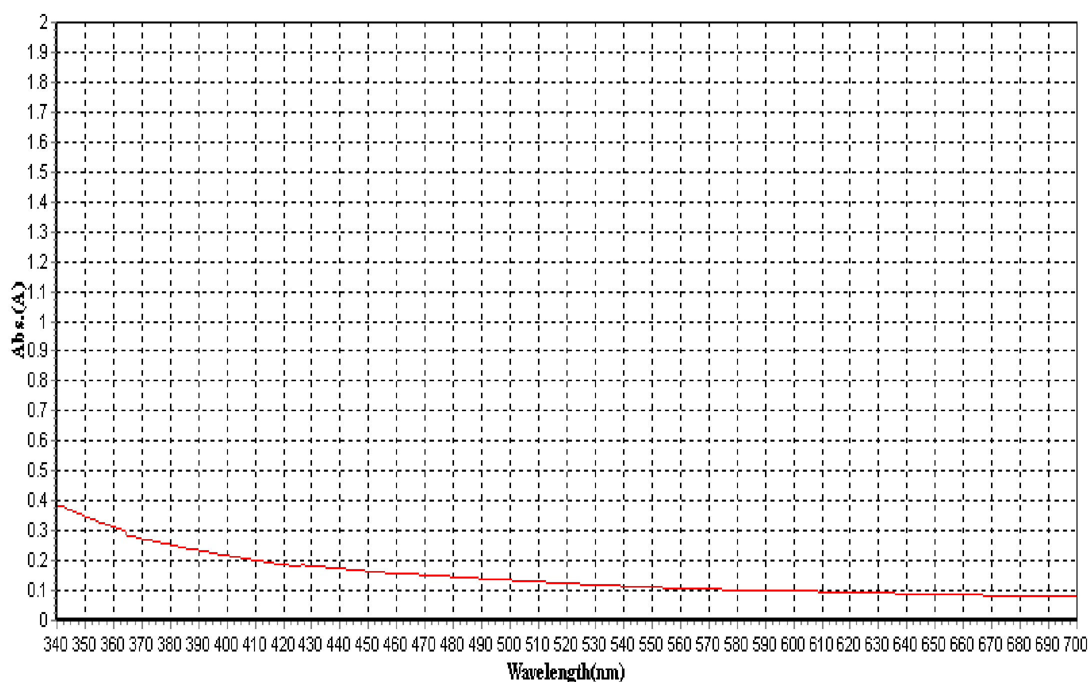
Figures (3.13.3): Optical absorption coefficients of aqueous honey (3%) versuswavelength.



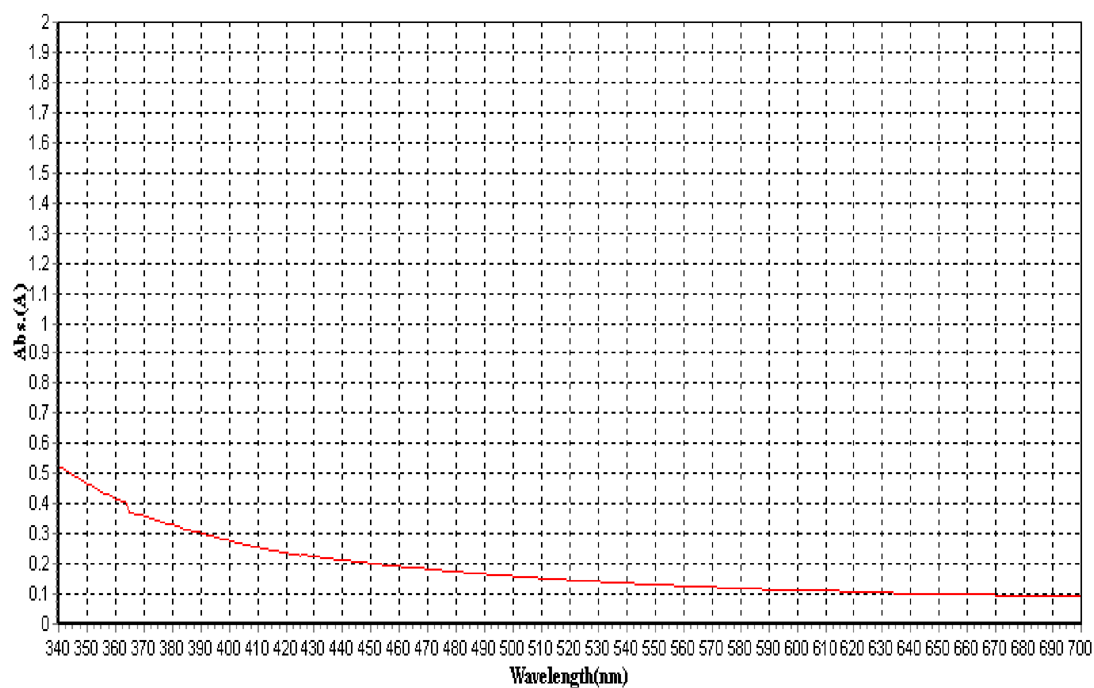
Figures (3.13.4): Optical absorption coefficients of aqueous honey (4%) versuswavelength.



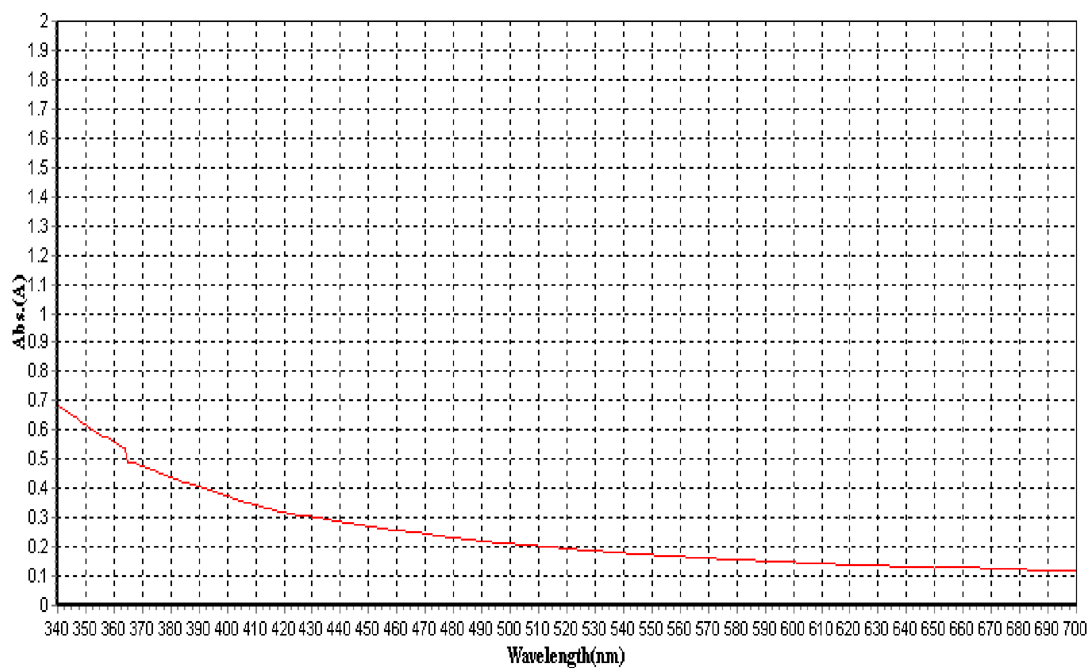
Figures (3.13.5):Optical absorption coefficients of aqueous honey (5%) versuswavelength.



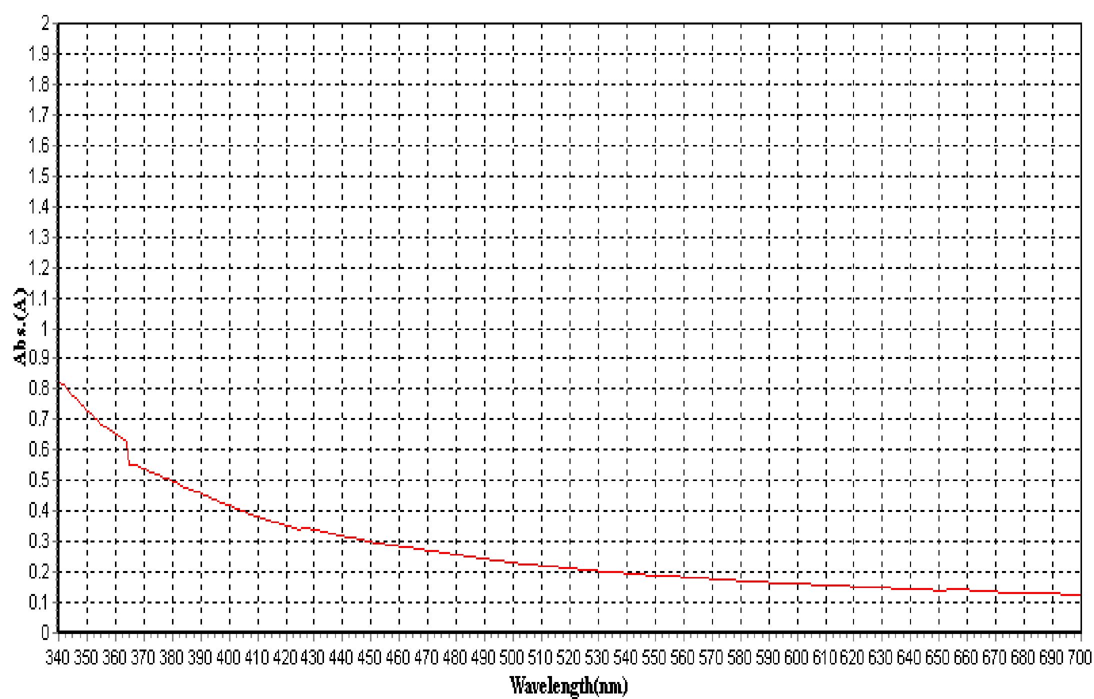
Figures (3.13.6):Optical absorption coefficients of aqueous honey (10%) versuswavelength.



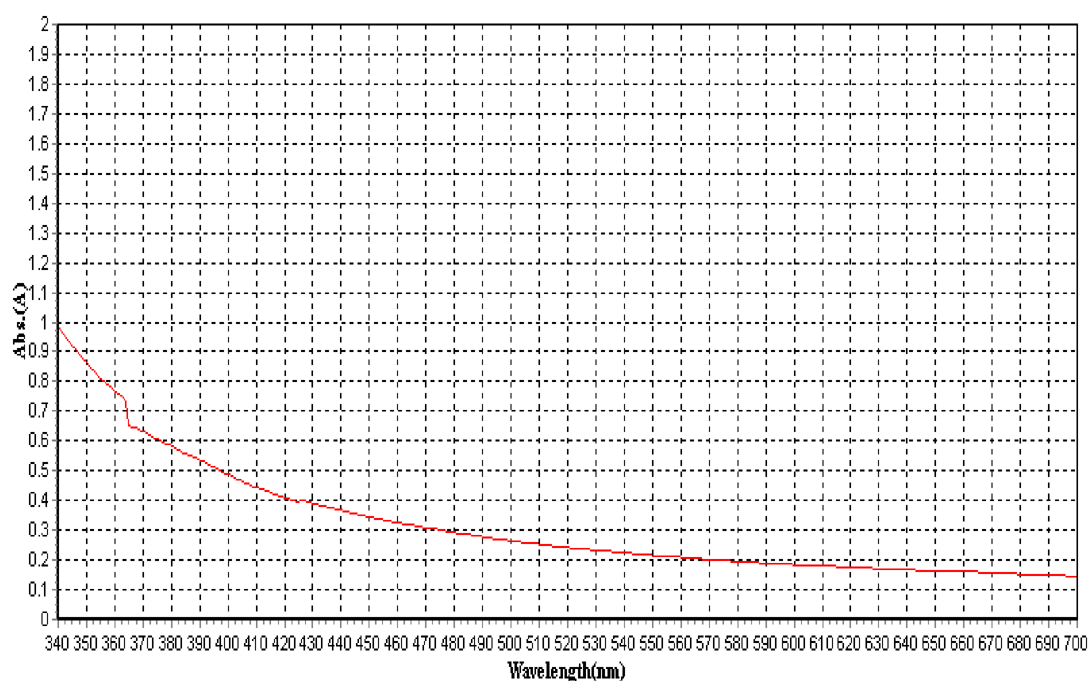
Figures (3.13.7):Optical absorption coefficients of aqueous honey (15%) versuswavelength.



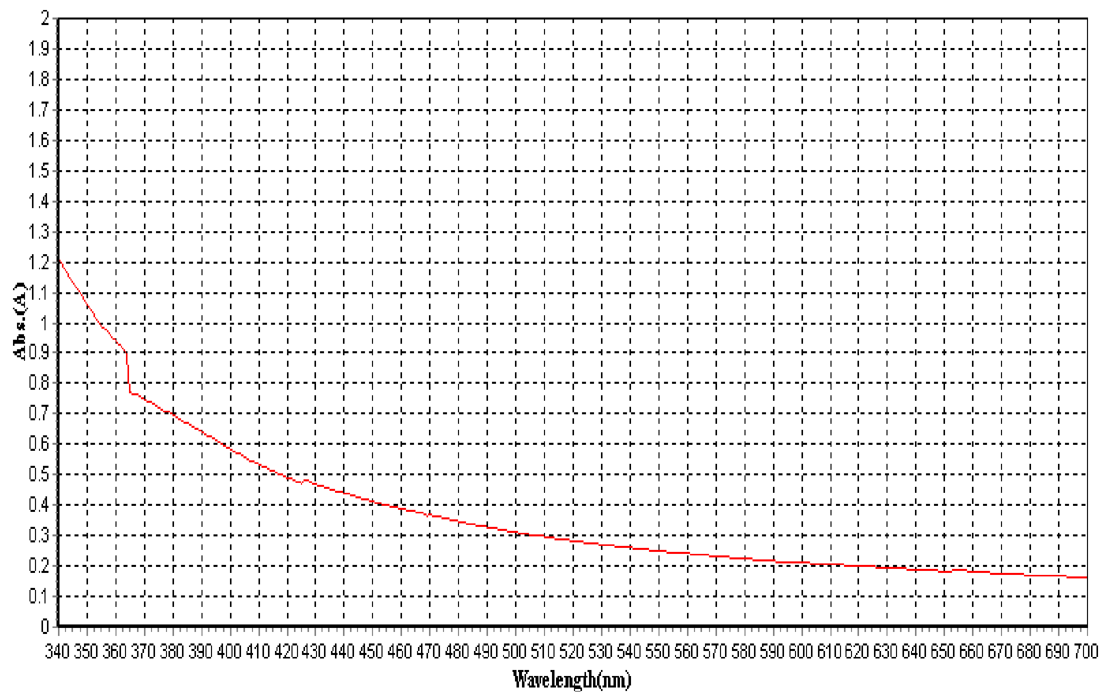
Figures (3.13.8): Optical absorption coefficients of aqueous honey (20%) versuswavelength.



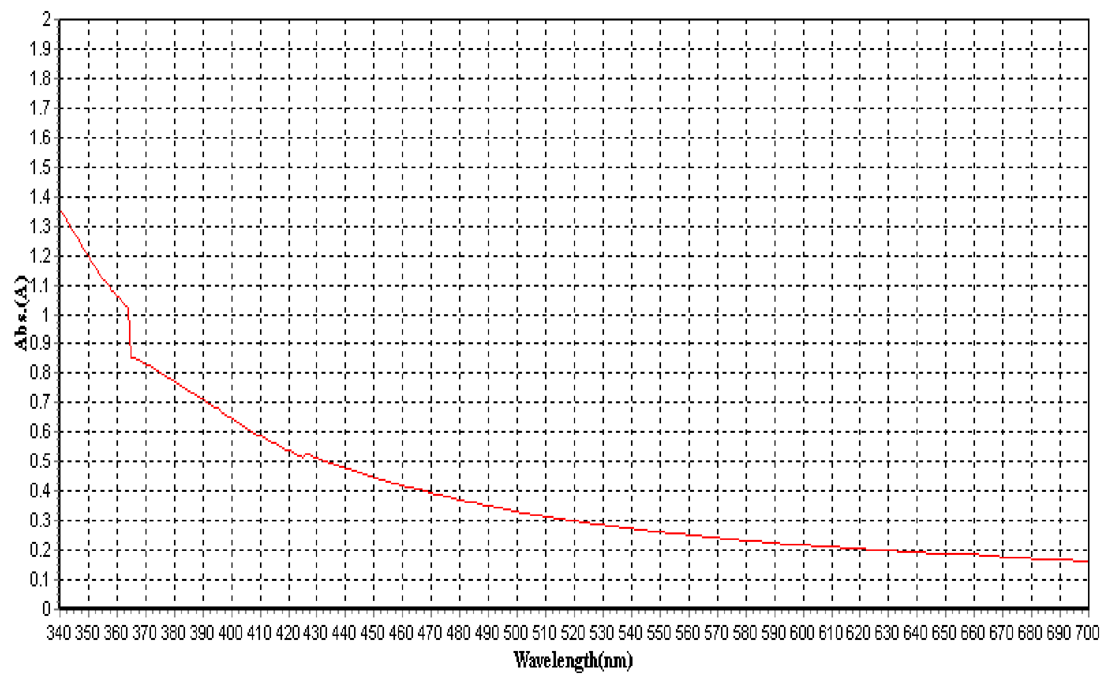
Figures (3.13.9): Optical absorption coefficients of aqueous honey (25%) versuswavelength.



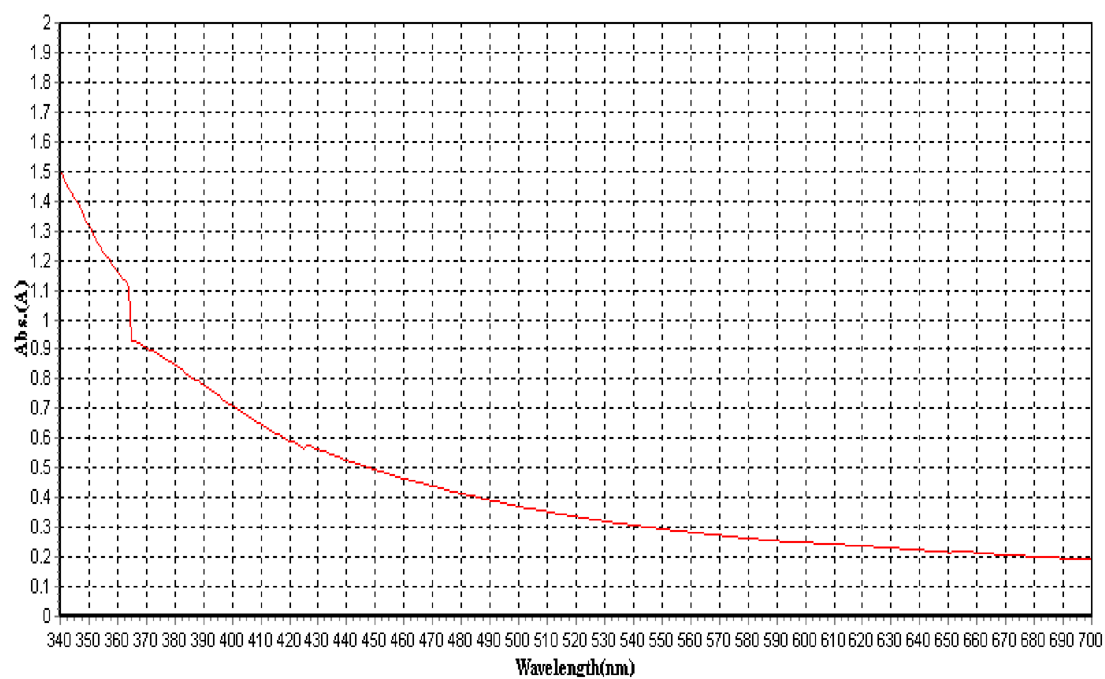
Figures (3.13.10):Optical absorption coefficients of aqueous honey (30%) versuswavelength.



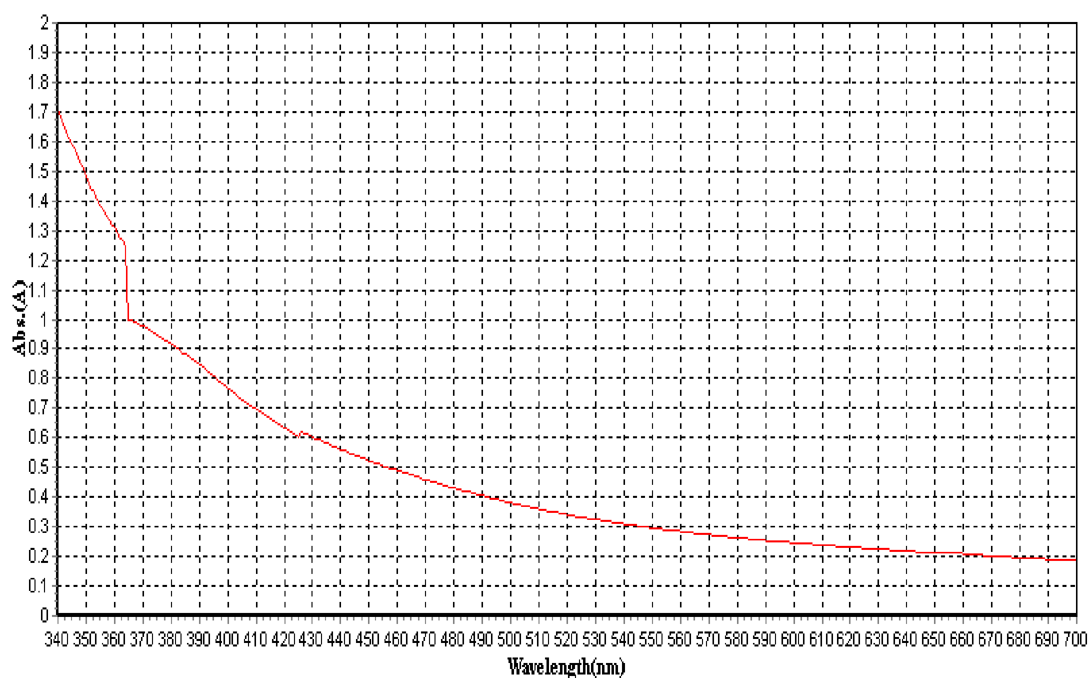
Figures (3.13.11): Optical absorption coefficients of aqueous honey (35%) versuswavelength.



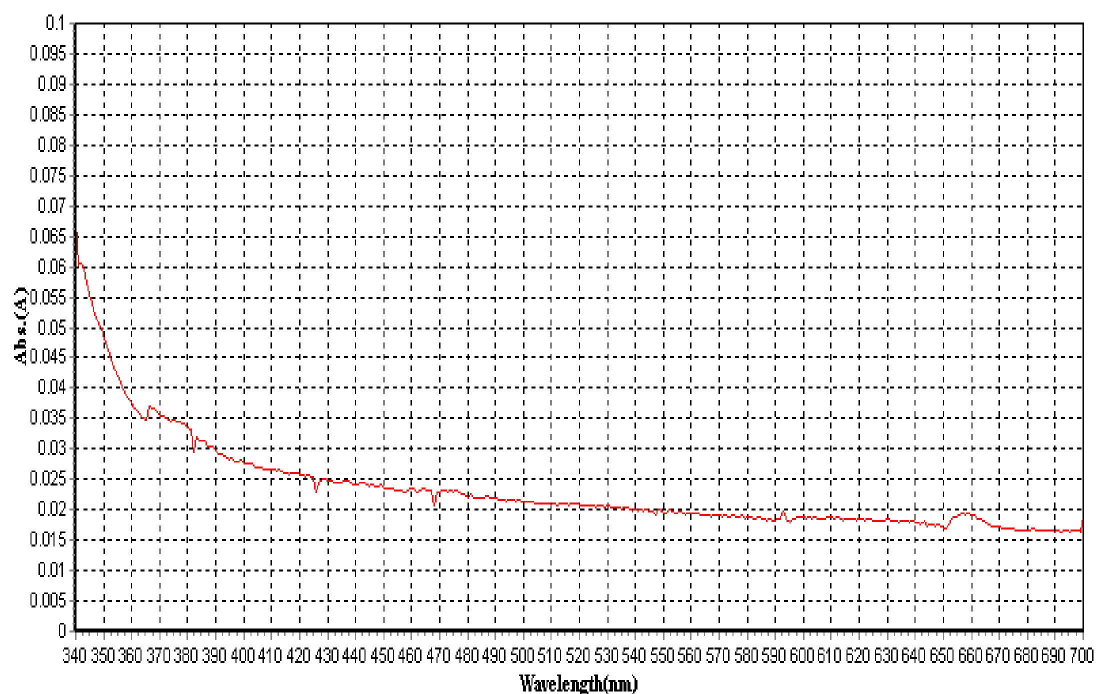
Figures (3.13.12): Optical absorption coefficients of aqueous honey (40%) versuswavelength.



Figures (3.13.13):Optical absorption coefficients of aqueous honey (45%) versuswavelength.



Figures (3.13.14): Optical absorption coefficients of aqueous honey (50%) versuswavelength.



Figures (3.13.15): Optical absorption coefficients of insulin versus wavelength.

The mineral content in pure honey sample have been measured using energy dispersive X ray fluorescence spectrometer and shown in figure (3.13.16).

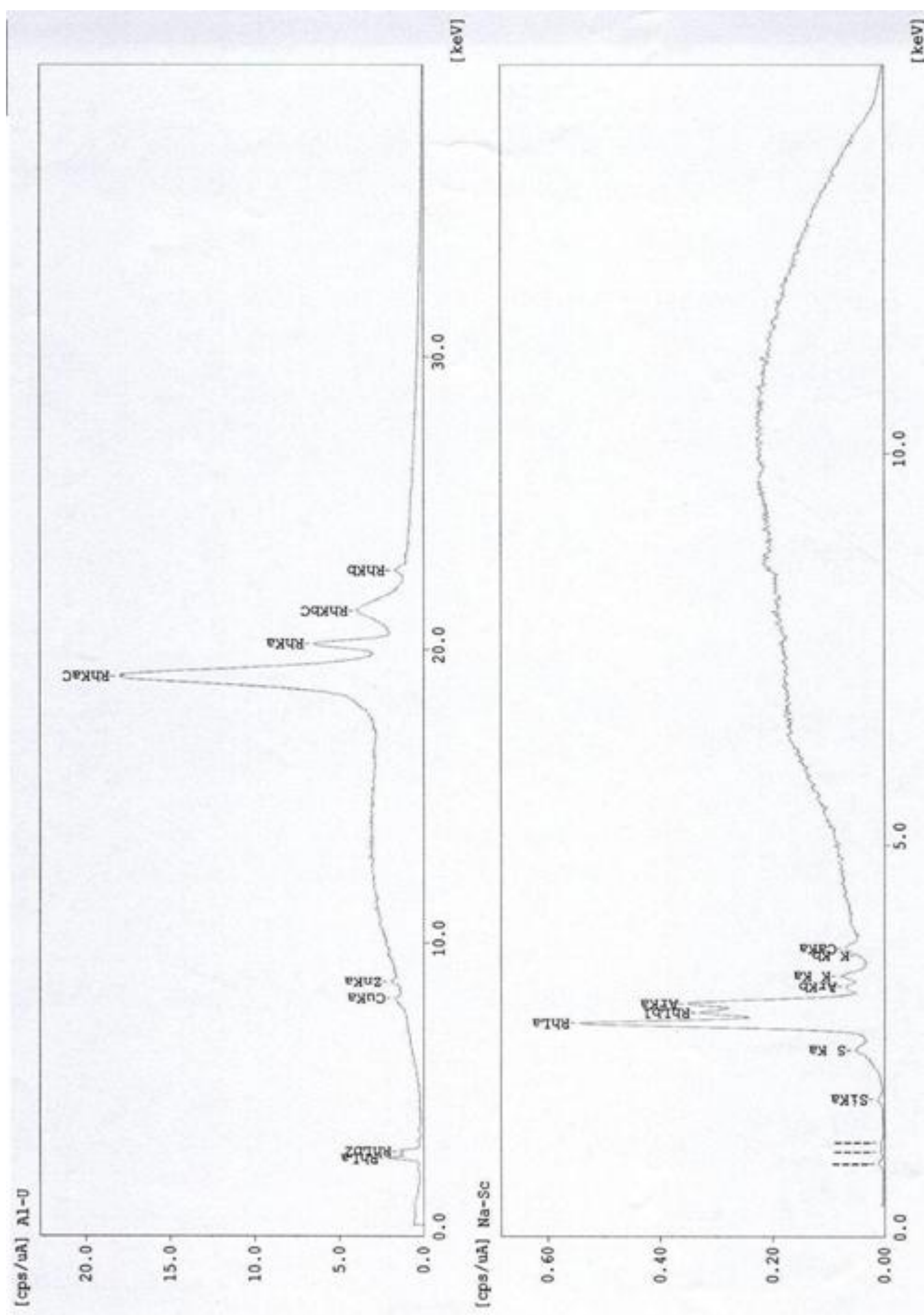


Figure (3.13.16): The mineral content in pure honey.

3.14. Conclusions

In this physical study we reported the measured and calculated of some structural (such as density, dry content, moisture content, pH and ash content), mechanical (such as viscosity, activation energy, sphere drag coefficient and water activity), thermal (such as entropy, enthalpy and

thermal expansion), electrical (such as permittivity, polarizability and susceptibility) and optical properties (such as refractive index, specific refraction, normal incidence reflectance, reflection factor, normal incidence transmittance and spectral absorption) for different concentrations of aqueous honey solutions (with honey concentrations 1%, 2%, 3%, --- 40%, 45%, 50%), aqueous glucose solutions mixed with one gram of insulin (with glucose concentrations 0.5%, 1%, 2%, 3%, 4%, 5%) and aqueous insulin solutions mixed with one gram of glucose (with insulin concentrations 0.5%, 1%, 2%, 3%, 4%) in the temperature range between 25 to 50^{o}C. The densities for all samples were pycnometrically measured. The refractive indices were measured at the required temperatures with the thermo stated highly précised Abbes refractometer at the visible D spectral line (Na, λ = 589nm). The dynamic viscosities were measured at the required temperatures using falling ball viscometer for all concentrations of aqueous honey and aqueous glucose insulin mixtures. Optical absorption, dry matter, ash content, moisture content and pH have been experimentally determined for aqueous honey samples. A comparative study has been reported for all samples between the specific refractions of different mixing rule equations (such as Lorentz Lorenz, Oster, Arago Biot, Newton, Gladstone Dale and Eykman) and between viscosities of different mixing rule equations (such as Reynolds, Grunberg Nissan and Mclaughlin Ubbelhold). The activation energies for all samples were calculated using Frenkel Eyring Arrhenius type equation.This scientific work gives the polynomial fitting equations of temperature gradients d/dT and concentration increments d/dC of all measured and calculated physical properties. From the results of this study we can mention the following conclusions:

1- The adulteration of honey can be easily obtained using the experimental measurements of refractive index, viscosity, density and spectral absorption.
2- Using the dynamic viscosity mixing rule equations of Grunberg Nissan and Mclaughlin Ubbelhold reveals that there is a mechanical interaction between aqueous glucose and insulin liquids.
3- This study verified that the specific refraction is independent on temperature for all theoretical modeling of mixing rule equations.
4- This research shows that the studied empirical relations give a good description of the temperature and concentration effects on specific refraction and dynamic viscosity.
5- The agreement between the calculated and measured values in this research with the values published in other scientific researches confirms the accuracy of used methods.

During this study the aim was to find a set of polynomial equations that describe the relationship between thermal gradients with temperature and concentration increments with concentration of all measured and calculated physical properties

References

Abu-Jdayil, B. Ghzawi, A. Al-Malah, K.I.M. and Sh. Zaitoun (2002). Heat Effect on Rheology of Light- and Dark- Colored Honey, **J. of Food Engineering** 51(1): 33-38.

Abramovic, h. jamnik, M. Burkan, L. and M. kac(2008). Water Activity and Water Content in Sovenian an Honeys, **Food Control** 19(11):1086-1090.

Adams, B.A. Osikabor, B. Olomola, A. AND A.A. Adesope (2010). Analysis of Physical and Chemical Composition of Honey Samples in Selected Market in Ibadan Metropolis, **Journal of Agriculture and Social Research** 10(2): 31- 36.

Adenekan, M.O. Amusa, N.A. Lawal, A.O. and V. E. Okpeze (2010). Physico-Chemical and Microbiological Properties of Honey Samples Obtained from Ibadan,**Journal of Microbiology and Antimicrobials** 2(8):100-104.

Ali, A. Nain, A.K. Chand, D. and R. Ahmad (2006). Viscosities and Refractive Indices of Binary Mixtures o Dimethylsulphoxide with Some Aromatic Hydrocarbons at Different Temperatures: An Experimental and Theoretical Study, **Journal of the Chinese Chemical Society** 53(1): 531-543.

Ando, Sh. (2006). DFT Calculations on Refractive Index Dispersion of Fluoro-compounds in the DUV-UV-Visible Region, **Journal of Photopolymer Science and Technology** 19(3): 351-360.

Attri, P.K. (2011). Physico-Chemical Investigation of Honey Samples of Apis Cerana Incica F. (Traditional Beekeeping) and Apis Mellifera (Morden Apiculture) from Chamba District, Himachal Pradesh, Biological Forum - **An International Journal** 3(1): 67-73.

Ayari, B. Abbassi, F. Hammami, M.A. and A. Landoulsi (2013). Physicochemical and Antimicrobial Properties of Tunisian Honeys:

Honey Inhibited the Motility of Bacteria, **African Journal of Microbiology Research** 7(32): 4138-4145.

Balammal, G. Muneeshwari, K. and P.H. Khan (2012). **Recent Trends in Insulin Drug Delivery Systems,** IJPDT 2(1): 20-28.

Barer, R. and S. Joseph (1954). Refractometry of Living Cells,**Quarterly Journal of Microscopical Science**, 95(4): 399-423.

Bashkatov, A.N. and E.A. Genina (2002). Water Refractive Index in Dependence on Temperature and Wavelength: a Simple Approximation, **Proceedings of SPIE**, 5068: 393-395.

Belie, T. (2009). Honeybee Production and marketing Systems, Constraints and Opportunities in Burie District of Amhara Region, Ethiopia, **Master Degree Thesis**, Bahir Dar University.

Beysens, D. and P. Calmettes (1977). Temperature Dependence of the Refractive Indices of Liquids: Deviation from the Lorentz-Lorenz Formula, **J. Chem. Phys.** 66(2): 766-771.

Bichang'a, R.R.M. (2010). Characterization of Kenyan Honey and a Design Model for Processing Equipment, **PHD Thesis in the School of Pure and Applied Sciences**, Kenyatta University.

Bin Mat Yunus, W.M. and A. bin Abdul Rahman (1988). Refractive Index of Solutions at High Concentrations, **Applied Optics** 27(16): 3341-3343.

Cantarelli, M.A. Pellerano, R.G. Marchevsky, E.J. and J.M. Camina (2008). Quality of Honey from Argentina: Study of Chemical Composition and Trace Elements, **The Journal of the Argentine Chemical Society** 96(1-2): 33-41.

Chen, J. Chen, X. Xu, R. Zhu, Y. Shi, Y. and X. Zhu (2008). Refractive Index of Aqueous Solution of CdTe Quantum Dots, **Optics Communications** 281(1): 3578–3580.

Declerck, P. (2007). Biologicals in the Era of Biosimilars: Implications for Naming and Prescribing, **European Journal of Hospital Pharmacy Practice** 13(1): 51-53.

Deosarkar, S.D. Pandhare, V.V. and P. S. Kattekar (2013). Densities and Refractive Indices of Potassium Salt Solutions in Binary Ethanol + Water Mixture of Different Compositions, **Journal of Engineering** Article ID 368576, doi.org/10.1155/2013/368576.

Deosarkar, S.D. Pandhare, V.V. and P. S. Kattekar (2013). Densities and Refractive Indices of Potassium Salt Solutions in Binary Ethanol + Water Mixture of Different Compositions,**Journal of Engineering** Article ID 368576, doi.org/10.1155/2013/368576.

Desbandhu, J. Parthiv, Ch. Kundan, P. Mithilesh, P. and T. Sanjay (2011). A Review on Diabetes**, International Research Journal of Pharmacy** 2(8): 22-25.

El-Bialee, N.M. and M.A. Sorour (2011). Effect of Adulteration on Honey Properties, **International Journal of Applied Science and Technology** 1(6): 122-133.

ElGhandoor, H. Elsharkawy, Y.H. El-Sherif, A.F. and R. M. Elghwas (2009). Determination of Glucose Concentration Using Optical Coherence Tomography,**International Conference on ASAT** 13: 1-12.

El-Zaiat, S.Y. (2007). Inherent Optical Properties of Zamzam Water in the Visible Spectrum: Dispersion Analysis, **The Arabian Journal for Science and Engineering** 32(2A): 171-180.

Erejuwa, O.O. Sulaiman, S.A. and M.S. Ab Wahab (2012). Honey: **A Novel Antioxidant**, Molecules 17(1): 4400-4423.

Feas, X. Pires, J. Iglesias, A. and M.L. Estevinho (2010). Characterization of Artisanal Honey Produced on the Northwest of

Portugal by Melissopalynological and Physico-Chemical Data, **Food and Chemical Toxicology** 48(1): 3462–3470.

Galisteo-Lopez, J.F. Galli, M. Patrini, M. Balestreri, A. Andreani, L.C. and C. Lopez (2006). Effective Refractive Index and Group Velocity Determination of Three-Dimensional Photonic Crystals by Means of White Light Interferometry, **Physical Review B, 73**(1): 5-9.

Gooch, J.W. (2010). **Encyclopedic Dictionary of Polymers**, Springer(1).

Gossain, V.V. (2003). Insulin Analogs and Intensive Insulin Therapy in Type 1 Diabetes, **International Journal of Diabetes in Developing Countries**23(1): 26-36.

Gupta, A. Srivastava, R. and A. Pandey (2012). Acoustical Studies on Molecular Interaction of Ascorbic Acid and Aqueous Sacharide Solutions at Different Temperature, **Global Advanced Research Journal of Chemistry and Materials Science** 1(3): 39-54.

Hamad, T.K. (2013). Refractive Index Dispersion and Analysis of the Optical Parameters of (PMMA/PVA) Thin Film, **Journal of Al-Nahrain University** 16(3): 164-170.

Hidayanto, E. Tanabe, T. and J. Kawai (2010). Measurement of Viscosity and Sucrose Concentration in Aqueous Solution Using Portable Brix Meter,**Berkala Fisika** 13(2): 23-28.

Jacobsen, S.E. and Ch.E. Wyman (2000). Cellulose and Hemicellulose Hydrolysis Models for Application to Current and Novel Pretreatment Processes**, Applied Biochemistry and Biotechnology** 84-86(1): 81-96.

James, O.O. Mesubi, M.A. Usman, L.A. Yeye, S.O. Ajanaku, K.O. Ogunniran, K.O. Ajani, O.O. and T.O. Siyanbola (2009). Physical Characterisation of Some Honey Samples from North-Central

Nigeria, **International Journal of Physical Sciences** 4(9): 464-470.

Joseph, T. Julius, A.N. Florence, F. Delphine, D.N. Jonnas, P. and M.Z. Antoine (2007). Physico-Chemical and Microbiological Characteristics of Honey from the Sudano-Guinean Zone of West Cameroon, **African Journal of Biotechnology** 6 (7): 908-913.

Kanchanalakshana, D. and A.J. Ghajar (1986). An Improved Falling Sphere Viscometer For Intemediate Concentrations of Viscoelastic Fluids, **International communications in Heat Mass Transfer** 13(1): 219-233.

Kang, E.S. Lee, T.H. and B.S. Bae (2002). Measurement of the Thermo-Optic Coefficients in Sol-Gel Derived Inorganic–Organic Hybrid Material Films, **Applied Physics Litters** 81(8): 1438-1440.

Khodier, S. (2002). Refractive Index of Standard Oils As a Function of Wavelength and Temperature, **Optics and Laser Technology** 34(1): 125-128.

Khowala, S. Verma, D. and S.P. Banik (2008). Biomolecules: Introduction, Structure and Function – Carbohydrates, **Drug Developement and Biotechnology of Indian Institute of Chemical Biology**, India.

Klofutar, C. Rudan-Tasic, D. and K. Romih (1997). Densities and Thermal Expansion Coefficients of Some Vegetable Oils, **Acta Chim. Slov.** 44(1): 45-55.

Kumar, V. and J.K. Singh (2010). Model of Calculating the Refractive Index of Different Materials, **Indian Journal of Pure and Applied Physics** 48(1): 571-574.

Lee, K. Kunjappu, J. Jockusch, S. Turro, N.J. Widerschpan, T. Zhou, J. Smith, B.W. Zimmerman, P. and W. Conley (2005). Amplification of the Index of Refraction of Aqueous Immersion Fluids by Ionic

Surfactants, **Advances in Resist Technology and Processing XXII** 5753(1): 537-553.

Li, J. and Sh.T. Wu (2004). Extended Cauchy Equation for the Refractive Indices of Liquid Crystals, **Journal of Applied Physics** 95(3): 896-901.

Li, W. B. Segre, P. N. Gammon, R. W. Sengers, J. V. and M. Lamvik (1994). Determination of the Temperature and Concentration Dependence of the Refractive Index of a Liquid Mixture, **The Journal of chemical physics,**101(6): 5058-5069.

Li, X. Cao, Z.Q. Shen, Q.Sh. Meng, Q.H. Huang, D.Y. Guo, K.P. Qiu, L. and Y.Q. Shen (2006). Anisotropy in Thermo-Optic Coefficient of Different Polymer Systems by Attenuated Total Reflection Configuration, **Chin. Phys. Lett.** 23(4): 998-1001.

Li, Y.X. Ke, Y. Li, J. Li, Y. Li, R. Chen, X. Mollah, S. and X. Wang (2013).Quantitation of Insulin Analogue Glargine and Its Two Metabolites M1 and M2 on Triple Quad 6500 and Triple TOF 5600 LC-MS/MS Systems in a Dog Toxicokinetics Study**,** J. **Analytical and Bioanalytical Techniques** S5(1): 1-8.

Lin, L. Li, H. and S. Xie (1999). Linear Method of Determining the Refractive Index of Biotissue, International **Conference on Biomedical Optics** 177, doi: 10.117/12.364384.

Luczycka, D. (2009). Methodological Aspects of Testing Electrical Properties of Honey, **Acta Agrophysica** 14(2): 367-374.

Manzoor, M. Mathivanan, V. Nabishah, G.H. Mir, G.M. and Selvisabhanayakam (3013). Physico-Chemical Analysis of Honey of APIS Cerana India and APIS Mellifera from Different Regions of Anantnag District, Jammu and Kashmir, **International Journal of Pharmacy and Pharmaceutical Sciences** 5(3): 635-638.

McNichols, R.J. and G.L. Cote (2000). Optical Glucose Sensing in Biological Fluids: an Overview, **Journal of Biomedical Optics** 5(1): 5-16.

Meeteen, G.H. (1999). **Refractive Index Measurement**, CRC Press LLC.

Mehra, R. (2003). Application of Refractive Index Mixing Rules in Binary Systems of Hexadecane and Heptadecane with n – AlKanols at Different Temperatures, **Proc. Indian Acad. Sci**. 115(2):147-154.

Narendra, K. Narayanamurthy, P. and Ch. Srinivasu (2011). Refractive Indices of Binary Liquid Mixture at Different Temperatures, **Asian Journal of Applied Sciences** DOI: 10.3923/ajaps.2011.

Nazarian, H. Taghavizad, R. and A. Majd (2010). Origin of Honey Proteins and Method for its Quality Control, **Pak. J. Bot.** 42(5): 3221-3228.

Neelamegam, P. and S. Krishnaraj (2011). Estimation of Liquid Viscosities of Oils Using Associative Neural Networks, **Indian Journal of Chemical Technology** 18(1): 463-468.

Nepton, S. (2013). Beta-Cell Function and Failure, INTECH **5(1): 115-126.**

Nigussie, K. Subramanian, P.A. and G. Mebrahtu (2012). Physicochemical Analysis of Tigray Honey: an Attempt to Determine Major Quality Markers of Honey, **Bull. Chem. Soc. Ethiop.** 26(1): 127-133.

Nyau, V. Mwanza, E.P. and H.B. Moonga (2013). Physico-Chemical Qualities of Honey Harvested from Different Beehive Types in Zambia, **AJFAND** 13(2): 7415-7427.

Pb, Piste and Ch. Pb (2013). Effect of Insulin–Disease and Syndrome, **International Journal of Research in Pharmaceutical and Biomedical Sciences** 4(1): 196-201.

Peterson, W.H. Fred, E.B. and J.A. Anderson (1920). Lactobacillus Pentoaceticus, Galactose, and Mannose by the Fermentation of Glucose, **Journal of Biological Chemistry**. 42(1): 273-287.

Rubalya, V.S. Aniruthaan, K. Jeyanthinathan, G. and P. Neelamegam (2013). Analysis of Vegetable Oil's Rheological Parameters using AT-mega 328 Microcontroller,**Research Journal of Pharmaceutical, Biological and Chemical Sciences** 4(3): 129-141.

Satoh, T. (2014). Molecular Mechanisms for the Regulation of Insulin-Stimulated Glucose Uptake by Small Guanosine Triphosphatases in Skeletal Muscle and Adipocytes, **International journal of molecular sciences** 15(1): 18677-18692.

Shafiq, H. Shahid, A. and M.Z. Farid (2014). Physico-Chemical Properties of Honey Produced in Central Region of Punjab, Pakistan, **Life Sciences Leaflets**52(1): 40-51.

Sheeja, V.S. Reddy, M.H. Joseph, J. and D.N. Reddy (2010). Insulin Therapy in Diabetes Management, **International Journal of Pharmaceutical Sciences Reviewand Research** 2(2): 98-105.

Shrayyef, M.Z. and J.E. Gerich (2010). Principles of Diabetes Mellitus, **Springer Science and Business Media**, LLC.

Singh, A.V. Sharma, L. and P.G. Bhaya (2012). Studies on Falling Ball Viscometry, **arXiv:Physics Flu-Dyn.** 1202.1400: 1-56.

Singh, V.K. Jaswal, B.B.S. Kumar, V. Prakash, R. and P. Rai (2013). Application of He-Ne laser to study the variation of refractive index of liquid solutions with the concentration, **J Integr. Sci. Technol.** 1(1): 13-18.

Sivasubramanian, S. Widom, A. and Y.N. Srivastava (2002). Thermal Superradiance and the Clausius-Mossotti Lorentz-Lorenz Equations, **arXiv:Con-Mat. Stat-Mech.** 0209017v1:1-6.

Spok, A. Twyma, R.M. Fischer, R. Ma, J.K.C. and P.A.C. Sparrow (2008). Evolution of a Regulatory Framework for Pharmaceuticals Derived from Genetically Modified Plants, **Trends in Biotechnology** 26(9): 506-517.

Subedi, D.P. Adhikari, D.R. Joshi, U.M. Poudel, H.N. and B. Niraula (2006). Study of Temperature and Concentration Dependence of Refractive Index of Liquids Using a Novel Technique, **Kathmandu University Journal of Sciences** 2(1): 1-7.

Tappy, L. and K.A. Le (2010). Metabolic Effects of Sweetened Beverages: Path Physiology and Mechanistic Insights, **CMRE Journal** 3(3): 13-18.

Tekin, N. and C. Tarimci (2006). Study of the Structure and Refractive Parameters of Diethylamine and Triethylamine, **Optics and Laser Technology** 38(1): 498–505.

Thormahlen, I. Straub, J. and U. Grigull (1985). Refractive Index of Water and its Dependence on Wavelength, Temperature and Deusity, **J. Phys. Chem. Ref. Data** 14(4): 933-945.

Tipvarakarnkoon, T. Blochwitz, R. and B. Senge (2008). Rheological Properties and Phase Change Behaviors of Coconut Fats and Oils, **Annual Transactions of the Nordic Rheology Society** 16: 1-7.

Tominaga, A. Shibata, T. Takayama, H. and S. Kojima (2012). Brillouin Scattering Study of Glass Transitions in Glucose Aqueous Solution, **Proceedings of Symposium on Ultrasonic Electronics** 33(1): 27-28.

Van Krevelen, D.W. (1972). **In Properties of Polymers: Correlation with Chemical Structure**, Elsevier, Amsterdam.

Vuksanovic, J.M. Bajic, D.M. Ivanis, G.R. Zivkovic, E.M. Radovic, I.R. Serbanovic, S.P. and M.L. Kijecanin (2014). Prediction of Excess Molar Volumes of Selected Binary Mixtures from Refractive Index Data, **J. Serb. Chem. Soc.** 79(6): 707–718.

Wallace, J.C. and G.J. Barritt (2002). Gluconeogenesis, Encyclopedia of Life Sciences, **Macmillan Publishers Ltd and Nature Publishing Group.**

Wankhede, D.Sh. (2012). Refractive Index, Molar Refraction and Comparative Refractive Index Study of Propylene Carbonate Binary Liquid Mixtures, **Acta Chim. Slov.** 59(1): 258-263.

Weiss, L. Tazibt, A. Tidu, A. and M. Aillerie (2012). Optical Properties of Water Under High Pressure, **Optical Systems for the Energy and Production Industries** 7(1):1-2.

Weiss, L. Tazibt, A. Tidu, A. and M. Aillerie (2012). Water density and polarizability deduced from the refractive index determined by interferometric measurements up to 250 MPa, **The Journal of Chemical Physics** 136, 124201: 1-8.

White, J. W. Jr.(1975). Moisture in Honey :-Review of Chemical and Physical Methods, **Eastern Utilization Research and Development Division**, U.S.Department of Agriculture, East Mermeid Lane.

Wiederseiner, S. Andreini, N. Epely-Chauvin, G. and Ch. Ancey (2011). Refractive Index and Density Matching in Concentrated Particle Suspensions: a Review, **Exp. Fluids** 50(1): 1183–1206.

Winkler, A.M. Bonnema, G.T. and J.K. Barton (2010). New Scheme for Polarimetric Glucose Sensing Without Polarizers, Proc. SPIE 7572, **Optical Diagnostics and Sensing X: Toward Point-of-Care Diagnostics**, 757204

Yadava, S.S. Singh, Y. and N. Kushwaha (2010). Densities and Viscosities of Alkylethanoates +Cyclohexane, +Benzene, +1,4-dimethylbenzene, and +1,3.5-trimethylbenzene at 308.15 K, **Acta Chim. Slov.** 57(1): 707–715.

Yaturu, S. (2013). Insulin Therapies: Current and Future Trends at Dawn, World J. of Diabetes **4(1): 1-7.**

Yogendraji, K.A. Priyanka, L. Nisha, S. and Sh. Ritu (2011). Newer Strategies for Insulin Delivery, IJRAP **2**(6)**:** 1717-1721**.**

Young, J.C. and A.N. Finn (1940). Effect of Composition and Other Factors on the Specific Refraction and Dispersion of Glasses, **Journal of Research of the National Bureau of Standards** 25(1): 759-782.

Zainab, A. Modu, S. Falmata, A.S. and Maisaratu (2011). Laboratory Scale Production of Glucose Syrup by the Enzymatic Hydrolysis of Starch Made from Maize, Millet and Sorghum, Biokemistri 23(1): 1 – 8.

Zaitoun, Sh. Ghzawi, A. Al-Malah, K.I.M. and B. Abu-Jdayil (2001). Rheological Properties of Selected Light Colored Jordanian Honey, **International J. of Food Properties** 4(1): 139–148.

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السنة : 2014-2015

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